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USAF PILOT PERCEPTIONS OF WORKLOAD ASSESSMENT IN A COMBAT OR HIGH-THREAT ENVIRONMENT

THESIS

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Preface

Integration of advanced technologies into the cockpits of new aircraft designs is an ever-growing concern of the United Air Force policy makers. New technologies bring extra responsibilities and add new challenges to the list of the tasks which USAF pilots are expected to master. As technology advances, so does the level of cockpit workload. To assess in-flight workload in combat or in a high threat environment, no proper measuring technique has been found. This study investigates pilot perception of cockpit workload in a high threat combat environment by collecting subjective opinions of USAF pilots.

This study surveyed the attitudes of pilots who had flown different types of aircraft in a combat to provide insights into workload measurement in combat. A total of 219 Air Force bomber, fighter, transport, air-to-air refueling, and tactical attack pilots with previous combat experience were surveyed. Respondents identified combat workload items with varying degrees of importance ranging from "distractingly" important to "a little or not" important. Overall, "distractingly" important combat workload items were similar for almost all types of aircraft as well as for most mission types flown in combat. Regardless of aircraft type or mission flown, Threat Avoidance and In-flight Emergency were dominant combat workload items. Pilot ratings for significant combat workload items were summed to assess the perception of in-flight workload of pilots on a combat mission. Means of Combat Workload Scores (CWL) for all aircraft types were not found to be significantly different. The study concluded that

combat workload can be measured by surveying the perceptions of pilots; however, the findings, based on subjective assessments, provide tentative grounds for further research.

Hereby, I would like to express my well-deserved thanks to special people who contributed to this research effort. Without them, this study would not have been completed. I would like to express my special thanks to my thesis advisor, Dr. David Kirk Vaughan, who guided my research effort from day one. He kept me on the track and helped me solve the formidable problems which I had as an international student. I also owe special thanks to Dr. Guy Shane for his help and guidance in assuring the accuracy of statistical analysis.

Second, I want to thank the pilots of 445th Airlift Wing at Wright-Patterson AFB, Ohio, and those of the Turkish Air Force, who participated in Red Flag in August of 1997. They reviewed the preliminary survey, and gave insights to shape the final format of the questionnaire. Next, I owe special thanks to my friends who helped personally with organizing and mailing out the survey packages. Their dedicated work saved considerable time and effort.

Finally, I want to thank my colleagues in the United States Air Force for taking time to answer my questionnaire. Their responses made this research possible. I hope that I interpreted their responses accurately, and presented the results as fairly as possible. I believe the conclusions driven from their responses will have an impact on future aircraft design efforts and in-flight workload assessment research.

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Abstract

This study analyzed the self-reported survey responses of 219 Air Force Pilots concerning their perceptions of workload assessment in a combat or a high-threat environment. The first objective of this study was to determine and compare the combat workload factors of varying importance in combat workload assessment by aircraft and mission type flown. The second objective was to examine the pilots' perception of combat mission in-flight workload. A stepwise regression model to predict the pilots' perceptions of in-flight workload using pilots' characteristics data was explored. Research conclusion varied among aircraft types. Combat workload items indicated as "distractingly" important were similar for all aircraft types, while items in lower level of importance were impacted by aircraft type. Mean Combat Workload (CWL) scores of pilots from each aircraft type were not significantly different. Overall, it was concluded that surveying pilots who had flown in combat or high-threat environments provided useful responses to assess pilot workload; however, findings based on subjective assessments, provide tentative grounds for further research.

USAF PILOT PERCEPTIONS OF WORKLOAD ASSESSMENT IN A COMBAT OR HIGH-THREAT ENVIRONMENT

I. Introduction

Chapter Overview

This chapter contains general background information relating to issues of in-flight workload measurement of pilots in combat environment. The specific problem statement, the purpose of the study, and investigative questions are presented as well as the associated hypotheses. Also included in this chapter are the assumptions of the study.

Background

Air operations depend on the aircrew's ability to employ all the capabilities of their weapons systems. However, with advanced weapons systems, aircrew tasks are becoming increasingly complex and time constrained, often near the limits of the aircrew's ability to perform required tasks. Faced with handling several sources of information concurrently, the pilot must decide on priorities. This becomes vitally important in a combat environment, where often an enemy threat is present.

When the pilot fails to prioritize concurrent tasks, he or she becomes task saturated. Often, primary task capabilities, such as the ability to keep the desired flight

path, are impaired due to task saturation, perhaps resulting in unsafe situations. If this is the case, flight training emphasizes the importance of flying the aircraft first, with navigation and communication as secondary responsibilities (Edwards, 1990: 190).

Task saturation and workload are closely related. Once the pilots have reached the limit of their mental capacity, they start to exert less control over the tasks and activities in the cockpit. The pilots are subject to mainly two kinds of workload while flying, physical workload and mental workload. Physical workload involves G forces, heat effects, air pressure effects, body and head movements, and other physical tasks like changing the position of switches. Often, these tasks are easier to measure by using physical scales such as heart rate, breathing rate, muscle tension, EKG, eye and eye lid movement. On the other hand, mental workload is not so easy to measure. Williges and Wierwille remark that two problems are apparent from a review of literature pertaining to mental workload: first, there is a lack of a single agreed-upon definition of mental workload, and second, there was is lack of a universal scale to measure it (Williges and Wierwille, 1979: 549). Harper and Cooper suggest that the two most common elements of pilot workload are: (1) What the pilot is required to accomplish with the aircraft and (2) The conditions or circumstances under which the required operation is to be conducted (Harper and Cooper, 1984: 11). On the other hand, Edwards simply describes workload as "the demand on the pilot" (Edwards, 1990: 133).

As aircraft systems become more complex, system performance and safety become critical issues in crewstation design. Both system performance and safety are dependent on operator workload. Recognizing this fact, all three military services,

NASA, and the Federal Aviation Administration (FAA) have been developing and evaluating empirical measures of in-flight workload (Jensen, 1989: 240). The Air Force Studies and Analyses and Aeronautical Systems Division/Equipment Engineering are two Air Force divisions which have become concerned with pilot workload. They add that the need to evaluate a system's potential effect on workload prior to the purchase of the system has become important, particularly in an age of high cost systems and reduced budgets (Groves and Kaercher, 1981).

Researchers have spent extensive effort and time on mental workload measurement studies. Some researchers, such as Wierwille et al in 1987, Moray 1982, and Gawron et al in 1989, updated the list of workload measures by reviewing the literature over time. They agree on four types of methods of measuring aircrew workload. They are: (1) Primary task performance measures, (2) Secondary task performance measures, (3) Physiological measures, and (4) Subjective measures.

Most of the measuring techniques utilize testing environments including different types of test batteries, flight simulators, or rotary or fixed wing aircraft. They used student or experienced pilots as well as non-pilot subjects, depending upon the resource availability or the purpose of the study. Use of test batteries is easy and inexpensive, while simulation requires more expertise from the stand point of both researcher and the subjects. Although simulation creates a more realistic environment in comparison to test batteries, simulators cannot provide an environment for most of the real world dimensions of pilot workload. For instance, pilot workload situations created by flying close to the ground on low level missions or by maneuvering to avoid a deadly enemy

missile are difficult to recreate in simulators. Real world measurements carried out on aircraft are expensive and risky, because measurement techniques used might adversely impact the mission success.

Problem Statement

Flying the high performance aircraft of today is probably one of the most challenging tasks that humans are given. Flying these aircraft requires high levels of physical and mental skills, particularly in a combat environment where the number of tasks can increase drastically. Measuring the physical and mental workload is vitally important to determine both the physical and cognitive capabilities of aircrew so that these limits are not exceeded, and new systems are designed accordingly. However, measuring of pilot workload in a combat environment by using some kind of a test battery in a rotary or fixed wing aircraft is not feasible. These measuring methods will degrade the pilot's performance or, at least, they will interfere with the flying tasks, where each task is extremely important to accomplish a combat mission. Using simulators as a testing environment for pilot workload measurement does not produce realistic results. A survey of pilots who have previous combat experience of any type should reveal a useful workload matrix in a combat environment with an existent enemy threat. Through such a survey, important aspects of in-flight workload assessment and inferences about pilot workload in high threat environments could be obtained. Findings of the survey might give insight regarding the efforts to measure workload in combat.

Research Question

The overall question that this research is trying to answer is: Based on the pilot experience, is it possible to assess pilot workload in a high threat combat environment?

The study is intended to investigate the pilot workload in a high-threat combat environment by collecting subjective opinions of USAF pilots currently flying AO/A-10, B-52, C-130, F-15, F16, and KC-135 aircraft. The results of the survey should provide insight to those interested in researching workload measurement in a combat environment without interfering with mission tasks, and to those willing to design operator systems that reduce the increased workload in the cockpit of a combat aircraft.

To answer the research question, the following specific questions and hypotheses are investigated.

Investigative Questions and Relevant Hypotheses

1. What pilot workload measurement systems have been developed that might pertain to a high-threat combat environment?
2. Is it possible to determine, from experienced pilots, what items would be most important in measuring workload in a high-threat environment?
3. Can any kind of consensus be reached to determine the relative priorities of workload factors?

3a. What do pilots of different aircraft type believe are the critical items that would increase their workload in a high threat combat environment?

Hypothesis #1: Pilots' perceptions of each aircraft type pertaining to the combat workload items will be different due to different characteristics of aircraft types.

3b. Does the level of workload perceived by pilots change depending on the type of the mission flown?

Hypothesis #2: The combat workload items' ratings of pilots will vary depending on the type of the mission flown.

3c. Does the level of workload perceived by pilots of each type vary by the experience level of the pilots?

Hypothesis #3: Perceptions of combat workload of pilots with more flight experience will be likely to be lower than those of inexperienced pilots.

3d. Is there a particular combat workload item that possesses significantly higher perception of workload by all pilots?

Hypothesis #4: The workload of "Threat Avoidance" is perceived significantly higher than other combat workload items by all pilots.

4. Is it possible to enumerate combat workload perceptions of pilots overall, or those of pilots from different aircraft, depending upon their characteristic data?

Hypothesis #5: A model could be developed to predict combat workload

perceptions of pilots in general, or those of pilots from particular aircraft by using pilots' demographic data as independent variables.

Assumptions

This study assumes that the pilots selected to participate in this survey represent an appropriate sample of the population of interest. It is also assumed that these individuals freely participated in the survey and provided honest answers to the questions.

Summary

This chapter has covered the general aspects of the workload measurement. The statement of the problem was provided in addition to the research question. Further, investigative questions were presented to detail the research question. In the next chapter, the published material pertaining to the in-flight workload measurement is investigated in detail.

II. Literature Review

Chapter Overview

This chapter reviews the published studies of researchers involved in efforts to measure the workload of operators such as pilots, space crew, and air traffic controllers. In this particular chapter, the various types of measurements are discussed according to their type and ability to measure in-flight workload. The review focuses mainly on those studies which are applicable to aircrew operating any type of Air Force rotary or fixed-wing aircraft.

The review of the existing literature includes four major types of workload measurement techniques:

1. Primary Task Performance Measurement Techniques
2. Secondary Task Performance Measurement Techniques
3. Physical Measurement Techniques
4. Subjective Measurement Techniques

Each technique is briefly described in the discussion that follows. Also in this chapter, the discussion of the purpose of the workload measures is included as well as the different methods described in the studies. Furthermore, the feasibility of measuring workload by using the listed workload measures is discussed in this chapter. Three studies which researched different aspects of aircrew flying issues during wartime operations by using similar or different methods were analyzed in terms of their relevance

to workload measurement in a high-threat setting. Finally, a summary of the findings gathered from the literature review is presented at the end of the chapter.

Measurement of In-flight Workload

As stated earlier, there is no single definition of aircrew workload and no single best way of measuring it. This is due to multi-dimensional feature of aircrew workload, which requires more than one type of measure to evaluate various aspects. The researchers agree that the appropriateness of a certain type depends on the purpose of the study.

A recent review of the related literature by Gawron, Schflett and Miller (1989) states that there are three uses for workload measurement. The first use predicts the workload of a particular system configuration for design purposes. The second use evaluates workload demands of existing systems for comparing systems or other workload measures, and for scheduling purposes. The third use of workload measurement is the online monitoring of workload. Such monitoring can be used in ways such that excessive workload could be reduced by restructuring the tasks performed by the pilot (Gawron et al. 1989: 241).

Several investigators have developed guidelines for selecting a proper workload measure for the purpose of the study. The most recent of guidelines, developed by Sequitur Systems, Inc. in 1988, includes the following seven criteria:

1. Sensitivity: the degree that a technique can detect changes in the amount of the workload imposed by the given task.
2. Diagnosticity: the extent that a technique can identify the human capabilities being used to perform the task
3. Intrusiveness: the extent that a workload measure degrades primary task performance.
4. Implementation Requirements: the practical constraints associated with the complexity of the measurement procedures or the apparatus.
5. Operator acceptance.
6. Reliability: the consistency of the data or results
7. Validity: the classical psychometric concept of validity including face, construct, content and predictive validity.

The review of the written materials indicates that not only is there no single agreed definition of workload, but also there is no single agreed categorization of workload. Some researchers name the categories differently. For instance, Wierwille and Connor (1983) group them under the following categories: opinion, spare mental capacity, physiological, eye behavior and primary task techniques. However, researchers have agreed upon the four types of workload measurement techniques mentioned earlier.

<u>The Primary Task Performance Measurement Techniques</u>

In a 1993 study, Wierwille and Eggemeier state that these type of techniques measure the operator's capability to perform the primary systems functions. Data about the operator's performance are typically obtained in a test and evaluation environment, and can provide an index of operator workload. They add that when such primary task measures are used to evaluate workload, techniques are applied with the expectation that the speed or accuracy of performance will decrease as workload increases beyond critical value or threshold for unimpaired performance (Wierwille and Eggemeier, 1993: 268).

Gawron et al (1989) list three types of primary performance techniques: Pilot Performance Index, Task Load, and Time Limits.

The Pilot Performance Index (PPI), developed by Stein in 1984, contains a list of performance variables and associated performance criteria for an air transport mission. The items in the list can distinguish experienced and novice pilots from each other. It is stated that the PPI is unable to measure the pilot performance effectively.

Task Load is defined as the time required to perform the task divided by the time available to perform the task. Any value above 1 indicates excessive workload. Gawron notes that this technique is sensitive to workload in flight environments.

The concept of Time Limits was developed by Gawron to identify dangerous situations and the performance of the pilot during these periods. These times include: time until impact, time until fuel is depleted, time until aircraft explodes or breaks apart, and other crisis-linked time limits.

The Secondary Task Performance Measurement Techniques

Secondary task scores were suggested as an index of workload and difficulty of certain primary tasks by Knowles in 1963. A study by Ogden, Levine, and Eisner (1979) states that the secondary task is used to determine how much additional work the operator can handle while still performing the primary job without deviating from desired level of performance. The authors note that this technique is also called as subsidiary task or auxiliary task (Ogden et al, 1979: 530). In this type of measurement, the subjects are

given two tasks concurrently, and asked to perform the auxiliary test giving emphasis on the primary task. The primary task might be determined or changed during the experiment by instructions from the experimenter.

Use of this technique involves the comparison of the performance of the secondary and the primary task together and that of solely the secondary task. The difference in performances indicates the magnitude of the workload imposed by the primary task. This type of measurement is based on the assumption that the secondary task does not interfere with the primary task performance. Another use of the technique includes the determination of the spare mental capacity, in which the performance of the subject on the secondary task indicates a scale for the difficulty of the primary task; the less the spare mental capacity the pilots have, the more the workload they experience.

Gawron et al list the five major types of secondary workload measurement. These include: Mental Arithmetic, Vigilance, Tracking, Time Estimation, and Sternberg Test. In the Mental Arithmetic technique, pilots are asked to perform basic arithmetic operations on sets of visually or aurally presented numbers while performing a primary task such as navigating, tracking, or piloting. The Vigilance technique requires pilots to respond either manually or verbally to the onset of visual or auditory stimuli. The Tracking tasks require the pilot to nullify the error between a desired and an actual course. The authors note that the Mental Arithmetic technique is useful when continuity is desired in workload measurement, and it is a proper technique when experimenting with simulators.

In the Time Estimation technique, pilots are asked to estimate a certain time interval (usually 10 seconds) starting with a visual or an aural stimulus while performing piloting tasks. The number of incomplete estimates or the length of the estimates might be used as an index of the workload of the primary task. The Sternberg Test requires pilots to determine if a given letter is a part of a previously memorized set of letters. The reaction times are measured at two different memory sizes (usually two- and four-letter sets) and plotted on a chart. The differences among the slopes of the various design sets indicate the differences in information processing demands.

Gawron et al remark that the major disadvantage of measuring secondary tasks is intrusion into the primary task, which is not desired in workload measurement. Besides, intrusion caused by a secondary task reduces the operator's acceptance of that measurement test dramatically.

After reviewing the post-1965 literature on the use of secondary tasks in assessment of the operator workload, Ogden et al. found twelve classes of tasks were used as secondary tasks. The most frequently used secondary tasks were choice reaction time, memory, monitoring and tracking. The other tasks included reaction time, classification, navigation, motor response, shadowing, detection and mental math.

Physiological Measurement Techniques

One of the most widely used methods of assessing pilot workload is use of physiological measures. Wierwille states that the underlying concept in physiological variables is as follows:

> As operator workload changes, involuntary changes take place in the physiological processes of the human body (body chemistry, nervous system activity, circulatory or respiratory activity, etc.). Consequently, workload may be assessed by the measurement and the processing of the appropriate physiological variables. (Wierwille, 1979: 575)

Wierwille adds that this technique assumes that changes in the workload cause increased emotional stress which is an intermediate variable causing physiological changes in the human body.

Gawron et al (1989) list the following nine physiological measurements of workload: Heart Rate, Heart Rate Variability, Weighted Coherence and Vagal Tone, Blood Pressure, Ventilation and Metabolic Rate, Spontaneous Electroencephalogram, Evoked Potentials, Endogenous Blinks and Visual Activities.

Heart Rate is typically measured by the number of the beats of the pilot's heart per minute. Measures are taken by electrocardiographs, as well as manual recordings of physical pulse rates. This measure has been used to compare the workload of pilots on different segment of the flights as well as among pilots of different aircraft types. Heart Rate Variability (HRV) is measured by the variability of interbeat intervals of the heart rates. Gawron et al note that HRV is affected by the breathing process. Weighted

Coherence and Vagal Tone techniques stem from the frequency analysis of HRV, and these techniques are reported to have applications in aviation psychology.

Blood Pressure is the measure of the body fluid's pressure exerted against the inner walls of the vanes. It is measured in units of inches or millimeters of mercury. This technique is used only for pre- or post-flight measurements, and the difference might provide an index for in-flight workload; however, it is affected heavily by the emotional status of the pilot and environmental factors like temperature and acceleration forces.

Ventilation and Metabolic Rate of lungs can provide various measures like ventilatory minute volume and breathing (ventilation) rates. According to Gawron et al, studies have proven that Spontaneous Electroencephalogram (EEG) (brain electrical signals) measures can provide a scale for pilot consciousness during in-flight operations.

Evoked Potentials are described as the changes in the amplitudes and latencies of cortical responses to external stimuli. It is reported that this measure is used minimally in flight due to difficulties of introduction of a well-defined stimulus into the task scenario (Gawron et al, 1989: 256).

Endogenous Blinks are different from exogenous blinks (reflex and voluntary blinks) as a result of the lack of an identifiable, external eliciting stimulus. Investigations of eye blink accompanied by event-recorded data could provide information about where the pilot's attention is focused. Studies show that the number of blinks decreases as the in-flight workload increases. Several other measurement data can be derived by examining the different visual cues provided by the pilot such as elapsed time between fixation on primary performance instruments, time spent monitoring in-cockpit versus

out-of-cockpit activities, and movement of the eyeball (rate and frequency) (Gawron et al, 1989: 257).

In addition to the list above by Gawron et al, in a review of physiological measurement techniques of mental workload, Wierwille (1979) lists the following measurement techniques: Flicker Fusion Frequency, Galvanic Skin Response and Skin Impedance, Electromyogram, Muscular Tension, and Body Fluid Analysis.

Flicker Fusion Frequency (FFF) exposes the subject (pilot) to the lowest frequency of flickering light source where it is perceived as a constant light source instead. The Galvanic Skin Response (GSR) technique measures the resistance of the skin tissue of the human body to the flow of low-level electrical current. On the other hand, Skin Impedance measures the resistance of the epidermal (skin) tissues to alternating current. An Electromyogram (EMG) measures and records the electrical activity of the epidermis caused by the electrical potential of the muscle under the skin.

Pilots often realize that various muscles in the body are tensed when the number of activities increases; for instance, leg and arm muscles' tension increase during close formation flight. Wierwille states that muscle size changes also can be used as a measure of the workload due to fact that tense muscles increase in size; however, in-flight measurement might require advanced apparatus.

Wierwille states that when a human being undergoes stress or becomes fatigued, changes may take place in the body's metabolic balance which are manifested in various body fluid compositions. Since sustained workload can induce stress and fatigue, it may

be possible to relate workload to these changes of the body fluid such as urine or parotid fluid.

Subjective Workload Measurement Techniques

Subjective workload measurements are commonly based on subjective opinions of the pilots about the magnitude of the workload they are exposed to. Wierwille and Eggemeier (1993) suggest that current results indicate that subjective techniques can be generally classified as globally sensitive indexes of workload (Wierwille & Eggemeier, 1993:267). Casali and Wierwille (1983) note that subjective measures have been widely used in pilot workload assessment due to their simplicity, flexibility, low cost and unobtrusiveness. Gawron et al (1989) list the following types of subjective workload measurement techniques: Subjective Workload Assessment Technique, Crew Status Survey, Profile and Mood States, Hart and Hauser Rating Scale, Flight Workload Questionnaire, NASA Bipolar Rating Scale, NASA Task Load Index, Analytic Hierarchy Process, Cooper-Harper Rating Scale, Bedford Workload Scale, Pilot Objective/Subjective Workload Assessment Technique, and Computerized Rapid Analysis of Workload.

The Subjective Workload Assessment Technique (SWAT) combines three different subscales under one measurement index including time load, mental effort load and physical stress load. This technique requires the pilot to rank workload from lowest to highest for each level of subscale. Pearson and Byes developed the Crew Status

Survey, composed of 20 statements where each statement describes different fatigue states. Eventually the number of the statements was decreased to seven statements besides blank space for general comments to simplify the scale. The abstract version of Profile and Mood States (POMS), which was developed by Shachem in 1983, provides measures for anger, vigor, fatigue, confusion and self-rated stress (Gawron et al, 1989: 260).

The Hart and Hauser Rating Scale was developed in 1987 to measure the workload for sustained flights by using a six-item rating scale. The six items, which used related rating scales from low to high extremes, include stress, mental/sensory effort, fatigue, time pressure, overall workload, and mission performance.

The Flight Workload Questionnaire utilizes a four-item behaviorally-anchored rating scale. Items include workload category (low to very high), fraction of time busy (seldom have much to do to fully occupied all times), difficulty of thinking/concentration (minimal thinking to a great deal of thinking), and state of feeling (relaxed to very stressful) (Gawron et al, 1989: 263).

The NASA Bipolar Rating Scale has ten subscales with subjective associated rating scales. Subscales consist of overall workload, task difficulty, time pressure, performance, mental /sensory effort, physical effort, frustration level, stress level, fatigue, and activity type (skill based, knowledge based and rule based). The NASA Task Load Index (TLX) is a multi-dimensional subjective workload technique in which workload is defined as efforts given by the pilot to achieve a certain level of performance. Subjective responses of pilots include emotional, cognitive and physical reactions as well as

weighted evaluations of their behaviors. The scales, with mostly low to high rating, include mental demand, physical demand, temporal demand, performance, effort, and frustration level (Gawron et al, 1989: 264).

The Analytical Hierarchy Process (AHP) asks pilots to compare all possible pair combinations to determine which condition has the higher workload. The Cooper-Harper (C-H) Rating Scale determines the handling qualities of newly designed aircraft systems, specifically, as used by the test pilots. Wierwille and Casali (1983) modified the original C-H rating scale to be able to assess the workload of the pilot. The Bedford Workload Scale is another version of the Modified C-H Rating Scale, which was developed by Royal Aircraft Establishment at Bedford, England. The Bedford Workload Scale uses the same binary-type rating scale with three- , four-, and ten-rank ordinal structure. The Pilot Objective/Subjective Workload Assessment Technique (POSWAT) is a ten-dimensional scale adopted from the modified C-H rating scale. It was developed by FAA Technical Center by using five categories of ratings as opposed to binary rating scale of the Modified C-H Rating Scale. The Computerized Rapid Analysis of Workload (CRAWL) is mainly used to assess the workload in systems being designed (Gawron et al, 1989: 265).

Feasibility of the Workload Measurement in High-Threat Environment

Almost all of the measurement techniques discussed previously require a test and evaluation environment or an advanced set of apparatus to collect data for evaluation.

These techniques generally impose intrusions into the primary mission of the operator. The subjective measures, even though the least obtrusive type of measurement techniques, require some kind of stiff surface board for the responses to be written on by the pilots. Some studies used audio recordings; nevertheless, they still cause degradation in primary mission performance.

The extensive review of the written materials on workload assessment reveals that there have been only a few studies done during real flight operations. A study by Wilson (1993) performed psycho-physiological workload analysis on the physiological and behavioral data collected on an air-to-ground mission on F-4 Phantom aircraft (Wilson, 1993: 1071). Another study by Skelly, Purvis, and Wilson used a physiological technique which collected three types of data (heart (ECG), eye (EOG) and brain (EEG) electrical signals) by use of pocket-carried physiological tape recorders (Gawron et al., 1989: 257). Only a few other in-flight workload assessment studies were performed on transportation and airborne refueling aircraft or rotary-wing aircraft, where the researchers had comfortable space for the apparatus to be utilized, as in the study conducted by Hill et al (1992). Numerous studies can be found in the literature which used simulators or test batteries in workload measurement. Simulators and test batteries, used individually or together, provide opportunities whereby various experimental designs in workload measurement can be implemented easily .

These facts strongly indicate that these measures will not be applicable to real world workload assessments endeavors in a combat environment where an enemy attack is imminent. This is mostly due to intrusion problems of the measurement techniques

and mission effectiveness concerns. A study by Neville et al, which is discussed in the next section in more detail, concludes that, unfortunately, no suitable methodology for measuring pilot performance in a wartime setting could be found (Neville et al, 1994: 346). Use of advanced simulators could be considered to assess the workload in such an environment; however, the effects of real threats are almost impossible to create in a simulation world.

Related Studies

Three previous studies researched different aspects of aircrew flying issues during wartime operations. However, they used similar or somewhat different methodologies to probe the issues. I have found it beneficial to include the discussions of these studies to point out the important issues mentioned in them. These studies include a quasi-experimental study of pilot fatigue in Desert Shield and Desert Storm by Neri and Shappell (1992), another quasi-experimental study by Neville et al (1994) that also investigated effects on fatigue during Operation Desert Storm, and an AFIT master's thesis by Starr and Welch (1991) which surveyed the USAF pilots' attitudes regarding replacing Weapon System Operator (WSO)/Navigator/Electronic Warfare Officer (EWO) with new cockpit technologies.

Neri and Shappell (1992)

Neri and Shappell investigated the effects of combat on the work/rest schedules and fatigue of 23 naval aviators aboard the U.S.S. America during Operations Desert

Shield and Desert Storm. They collected daily activity logs and recorded subjective fatigue measures during a four-week period while aviators operated in the Red Sea combat theater. They probed the indications of fatigue and sleep disorders induced by combat operations.

Neri and Shappell used a six-item survey card which volunteer pilots and radar intercept officers of F-14 Tomcat and A-6 Intruder aircraft aboard the carrier filled out after completing a day or night mission. Data collection started as soon as the U.S.S. America departed Norfolk, Virginia, on December 28, 1990 for the Red Sea. Operation Desert Storm started in the morning of January 16, just the next day after the arrival of the carrier in the theater. The researchers gathered the two-week data while the carrier passed seven time zones during her cruise. They also collected two-week data when the carrier anchored in the Red Sea combat theater during Operation Desert Storm.

They investigated the sleep quality of pilots and possible effects of combat such as sleep disorders. They also examined the effects of passing several time zones in a short time period on the sleep patterns of the aviators during and in the aftermath of the cruise. They claimed that studying the issue would help the collection of valuable information about military sleep management.

Neri and Shappell found that the aviators flew frequently at night without significant sleep problems or fatigue. They claimed that a likely factor was the excess amount of military assets in the combat theater, which allowed the workload to be shared by other units. The investigators pointed out other contributing factors, such as the effect of the eastward travel on pilots' circadian pacemakers. They stated that the inability to

adapt to the seven-time zone-change allowed pilots to fly the night missions around 0300 hours local time (2000 EST) without significant sleep problems. Neri and Shappell concluded that the work and rest schedule of critical combat personnel such as certain aviators, Special Forces' members, and advanced weapon operators could be revised to benefit from the side effects of circadian desyncronization (Neri and Shappell, 1991: 160).

This particular study is unique in studying the effects of combat on pilot performance in the real world environment. Similar studies could be performed to investigate the workload of the pilots in a real combat environment. The possibility of a major regional conflict like Operation Desert Storm occurring is hard to determine and it is highly undesired. Nevertheless, investigators should not disregard the future opportunities to assess the workload of pilots during wartime operations.

Neville, Bisson, French, Boll and Storm (Neville et al, 1994)

Like Neri and Shappell (1992), Neville et al (1994) investigated the effect of pilot fatigue on mission performance during Operation Desert Storm. Neville et al collected subjective fatigue ratings of eleven C-141 pilots from the 437th Military Airlift Wing, Charleston AFB, South Carolina, by using School of Aerospace Medicine (SAM) fatigue scale and Profile of Mood States (POMS) in addition to Digital Flight Data Recorder (DFDR) performance data. Data collection included a time span starting on March 16, a week prior to end of war, and ending on April 11, 1991.

On the SAM fatigue scale card, aircrew record subjective perception of fatigue experienced on a scale ranging from 1 to 7. The scale consists of following ratings: 1) fully alert, wide awake, very peppy; 2) very lively, responsive, not at peak; 3) okay, somewhat fresh; 4) a little tired, less than fresh; 5) moderately let down; 6) extremely tired; and, 7) completely exhausted, unable to function. The card also asks information about caffeine consumption, location of mission, and activities on half-hourly basis. Subjects recorded fatigue ratings and oral temperature every four hours, unless they were asleep. The other subjective fatigue measure used in the study, POMS, was developed by McNair, Lorr, and Droppleman (1971). The POMS, which consists of 65 adjective ratings, were used to record crews' perception of fatigue at the beginning of each crew rest period and the "legal-for-alert" period (Neville et al, 1994: 342). Ninety-six digital flight data recordings, obtained by DFDR, containing flight performance data on 138 approaches, were used in analysis, 78 of which were ILS approaches.

To evaluate the effectiveness of crew rest, Neville et al compared the POMS taken at two different times by performing an analysis of variance (ANOVA). In the analysis of aircraft performance, an 80-second segment of the last 90-second portion of each approaches is evaluated, excluding the last 10-second segment in which pilots transitioned to visual cues for touchdown. The mean indicated airspeed (IAS) readings within the 80-second period were averaged to analyze performance data. Addition to IAS, heading deviations were analyzed to evaluate the performance of pilots.

Neville et al report that analysis of POMS indicates that aircrew members were able to recover from the high levels of fatigue at the start of crew rest. They add that

crew members suffered high levels of fatigue at the end of missions and possibly during the final few hours of missions. Neville et al found that recent flight and sleep histories are correlated with high levels of fatigue. Analysis of flight performance data revealed that aircrew members experiencing higher levels of fatigue have tendency to make more mistakes.

Like the study by Neri and Shappell, this particular study pursues a similar method in studying the effects of combat on pilot performance in the real world environment. Use of DFDR to evaluate the pilot performance could be adopted to assess the pilot workload in a combat environment; however, the data should be supported by simultaneous cockpit aural or visual recordings to verify performance deviations. Possible correlation between workload and flight performance could be evaluated by using such recordings.

Starr and Welch (1991)

Starr and Welch surveyed 404 U.S. Air Force pilots regarding their perceptions of replacing the WSU/Navigator/EWO with advanced cockpit technologies. They also examined the impacts of such replacement on combat mission effectiveness. Their survey analyzed the responses of pilots from A-10, B-52, C-130, F-15E, F-16, and KC-135 units to investigate the possible differences in responses by the aircraft type.

Their survey, which contained 80 items, consisted of two parts. The first part was developed solely to acquire the demographic data to differentiate the various experience levels of the respondents by aircraft type. The second part was developed to collect data

to accomplish the four goals of the study. The first objective was to compare mission effectiveness factors that are always critical and almost always critical to the success of the success of the mission. The second objective was to examine, from the pilots' point of view, the WSO/Navigator/EWO impact on combat mission effectiveness (NAVCRIT). The third objective was to examine the WSO/Navigator/EWO's contribution to overall combat mission effectiveness (REQ)

Starr and Welch determined 31 mission effectiveness factors presented in the second part of their survey through the review of the related literature and interviews with the authorities. Pilots were then asked to rate each factor using a five-point Likert scale with the following choices: 1) Always Critical to Mission Success, 2) Almost Always Critical to Mission Success, 3) Can be Critical, 4) Almost Never Critical, and 5) Never Critical. Most of these factors, which are applicable to the purpose of the present research, were either rephrased or used directly.

The researchers utilized surveyed pilot demographics to predict NAVCRIT and REQ by a stepwise regression model. NAVCRIT was a variable which measured the impact of a WSO/Navigator/EWO on the specific combat mission effectiveness factors selected as critical by a particular pilot. REQ was the variable researchers used to measure a pilot's perception of the requirement for a WSO/Navigator/EWO for a specific mission. As the independent variables, they used the aircraft type, total flying hours on the current aircraft, total flying hours, previous aircraft qualification, flying experience with WSO/ Navigator/EWO, combat flying hours in the current aircraft, total combat flying hours, experience as an instructor pilot in an operational aircraft, experience as a

flight evaluator, experience as a wing weapon and tactics officer, participation in any major exercise, and the current rank of the respondents.

Upon examination of NAVCRIT and REQ scores, Starr and Welch found that the pilots' perceptions of WSO/Navigator/EWO contribution to combat mission effectiveness varied by aircraft type. Nevertheless, the "always critical" mission effectiveness factors were similar across all aircraft types. From the data gathered by reviewing the literature and surveying the 404 USAF pilots, the researchers concluded that the pilots of USAF aircraft did not believe it is possible to effectively replace the WSO/Navigator/EWO with technology for aircraft performing high threat combat missions.

The importance of this particular study is twofold. First is the similarity of the methodology to that proposed in this thesis. Second is the close relationship between mission effectiveness factors and the combat workload factors that impact the pilot workload. The probable relationship between these factors could be observed by analyzing the survey results.

Although the three studies detailed above investigate the some aspects of the pilot workload by including questions regarding the pilot workload, they do not suffice to draw significant inferences about the perception of the pilot's workload in combat. This study intends to explore these factors to point out the probable problem areas of workload assessment of pilots in combat.

Summary

There have been various attempts to measure the workload in flight which resulted in development of new techniques within last three decades. Investigators agree that there is no single best technique to measure workload.

Selection of a proper workload measure depends on the purpose of the study. A 1988 study by Sequitor Systems, Inc. lists the following seven criteria that should be considered while selecting a measure for workload assessment. These criteria are: sensitivity, diagnosticity, intrusiveness, implementation requirements, operator acceptance, reliability and validity.

The workload measurement techniques are grouped under four categories: (1) Primary Task Performance Techniques, (2) Secondary Task Performance Techniques, (3) Physiological Measurement Techniques, and (4) Subjective Techniques. Wierwille combines primary and secondary task performance techniques under one name of "performance related measurement techniques."

Reviewing the material on assessment of pilots' in-flight workload revealed no existing and suitable method of measuring workload in an aircraft while performing high threat combat missions. However, three studies researching different aspects of pilot operations in combat environment were discussed.

Due to implementation requirements of the most measures, it is hardly feasible to use these measures in the real world environment. Specifically, the use of these techniques in a combat environment with existing enemy threats becomes almost impossible due to intrusiveness of the techniques and their impact on mission

effectiveness. Therefore, a survey of pilots with combat experience might reveal valuable information about workload in such an environment.

In the next chapter, the methodology followed in this study is discussed, as well as the description of the survey questionnaire.

III. Methodology

Chapter Overview

This chapter describes the methodology of the study including the survey instrument by which the data of the study were collected. It also includes the discussion regarding the survey construction and testing. Furthermore, this chapter covers the general description of the population and sample surveyed. Also in this chapter, reliability and statistical tests used in data analysis are described.

Survey Instrument

The survey questionnaire presented in Appendix A was used for data collection. To assure the anonymity of responses, questions about individuals' name, social security number, and duty location were excluded from the survey questionnaires. Respondents were instructed not to put their names on any of papers to be returned.

Survey Construction and Testing

The survey questionnaire was designed in compliance with Air Force Instruction 36-2601 (AFI 36-2601, 1995: 1) and the Graduate School of Logistics and Acquisition Operating Instruction 53-10 (LA/OI 53-10, 1997:1). During the survey construction misleading and ambiguous questions were avoided as much as possible. Because the

survey questionnaire was designed to collect data from personnel flying different aircraft, each respondent was provided with an appropriate answer on each item.

The survey the survey consisted of 53 questions and was composed of two main parts, personal characteristics and combat workload items.

Personal Characteristics

The first part of the questionnaire, personal characteristics, included eight questions about demographic and experience items of the respondents. Eight items collected information about respondents including current rank, gender, total flight hours, the current/most recent aircraft, the previous aircraft, combat flight hours, aircraft and mission type flown in combat. These questions were asked to determine the experience level of each pilot. Questions regarding gender were asked to study the differences that might exist between the members of each group.

Combat Workload Items

The second part of the survey, combat workload items, consisted of two groups of questions. The first group of questions, Questions 9 to 37, contained 29 combat workload items. Pilots were asked to evaluate each item in terms of the degree to which they believed each item was likely to increase the pilot's workload in a combat environment, using a five-point Likert scale. Most of the items were taken from an AFIT study by Starr and Welch (1991) but reworded for the purpose of this study. Other items

were added based on the flight experience of the advisor, the author, and other pilots during the individual reviews of the questionnaire in survey construction phase.

The combat workload items were selected according to their potential impact on increasing the cockpit workload of the pilot in a combat environment. Maximum effort was made to select combat workload items applicable to all aircraft types included in the research. Nevertheless, due to fact that some of combat workload items might not apply for each aircraft type, the "not applicable" choice was included in the choices apart from five-point Likert scale. By the help of this separate choice, those workload items which did not apply to the pilots of aircraft not performing certain tasks could be categorized separately.

The twenty-nine combat workload items were listed without providing an operational definition. Many items conveyed different meanings depending on the aircraft type flown. These items were worded in a such way that the pilots filling out the survey could interpret the precise meaning of a particular item in their own operational terms. These items were listed in random order.

Pre-test groups from two aircraft types were asked to evaluate the validity of the combat workload items. The complete list of the 29 combat workload items is presented below in the order that they appeared on the survey questionnaire. Those items taken directly from the previous questionnaire used in the masters' thesis by Starr and Welch (1991) are indicated with an asterisk, and those items reworded for the purpose of the study are indicated by a double-asterisk.

1. Mission Planing*
2. Terrain Avoidance/Following *
3. Maintaining Situational Awareness**
4. Adverse Weather *
5. Monitoring Flight Instruments**
6. Equipment Degradation **
7. Low Level Navigation *
8. Night Low Level Navigation *
9. Threat Avoidance *
10. Formation Responsibilities **
11. Management of Time Over Target (TOT) *
12. In-flight, No-Notice Mission Changes*
13. Shifting Attention to Targets of Opportunity **
14. Munitions Employment *
15. Threat Detection *
16. Crew Incapacitation
17. In-flight Emergency **
18. Visual Orientation **
19. Command & Control (such as copying & decoding EAMS)**
20. Fatigue **
21. Crew Coordination **

22. Aircraft Maneuvering (Dogfight or avoiding the threats)**

23. Target Acquisition *

24. Type of the Drop

25. Night Operations *

26. Unfamiliar Terrain

27. Managing Radio Communication

28. Refueling Operations

29. Responding to Ground/Airborne Controller Instructions.

The definition of each choice in the five-point Likert Scale indicating severity of workload distraction was provided in the beginning of the second part of the survey. A copy of the survey questionnaire including these definitions is provided in Appendix A. The choices of the five-point Likert Scale are listed below:

1. Dangerous increase
2. Distracting increase
3. Moderate increase
4. Some increase
5. Little or No increase

At the end of the list of combat workload items, the respondents were allowed to list additional workload items that they thought would be likely to increase pilot workload in a combat environment.

The second group of questions, Questions 38 to 44, consisted of statements which asked pilots to evaluate these statements in terms of the degree to which they agreed with

them. All five questions were worded in such way that they might apply to all aircraft types. Questions 38, 39, 40, 41, and 44 were used to obtain information about pilots' perceptions on measures to reduce workload. The five questions are listed below:

38. Additional aircrew could reduce the workload in a combat environment (Assuming that your aircraft could be designed in such a way to accommodate the additional aircrew such as Weapon Systems Officer (WSO), Electronic Warfare Officer (EWO), Navigator, or Radar Intercept Officer (RIO).
39. Modifying the cockpit resources of your aircraft could help to eliminate the excess workload in the cockpit of the aircraft you flew in combat.
40. Technological innovations in future aircraft designs will help reduce the workload.
41. Updating the current operational regulations and procedures could help eliminate excess workload in the cockpit of the aircraft you fly or the most recent aircraft you flew.
44. In combat, the superiority of the U.S. and allies' air power over that of enemies will have an positive impact in reducing the amount of workload experienced during in-flight operations.

In question forty-two, pilots were also asked for their opinions about the comparison of combat and peace-time pilot workload. Question 42 stated that the workload of combat flight operations is heavier than that of peace time operations. In Question 43, pilots were questioned about the effectiveness of simulator training.

Question 43 was stated as follows: Simulator missions flown in peace time adequately simulate the amount of workload that a pilot will experience in combat.

For Questions 38-44, the respondents used a five-point Likert Scale to answer the questions in this group of questions. The scale included the following response choice;

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

Questions 44a through 45a solicited information regarding peacetime/pre-combat scenarios or procedures that pilots thought that would be most difficult to respond to in combat. They were also asked whether the scenarios or procedures were harder to react to in real combat situation.

In the second group of questions in Part II of the survey questionnaire, pilots were asked to express their willingness to participate in any experimental studies that measure workload using data collected in flight in a combat environment and in simulated combat missions. Answers to this question could provide insights to future researchers. At the end of the survey, respondents were encouraged to make additional comments about the issues discussed in this survey.

Survey Pre-testing

A preliminary version of the survey was administered to the following three groups: 1) pilots in the 445th Airlift Reserve Unit at Wright-Patterson AFB, OH; 2) pilots from several Turkish Air Force tactical fighter squadrons who attended the Red Flag Exercise in August 1997 at Nellis AFB, NV; 3) pilots attending the Air Force Institute of Technology (AFIT) Graduate School of Engineering. As result, fourteen F-16 pilots, 11 C-141 pilots, and two F-15 pilots were pretested.

Of the 40 surveys administered to the Turkish pilots, who all fly F-16s, 11 surveys were returned; and, of the 20 surveys administered to the 445th Airlift Reserve Unit, who fly C-141s, 11 surveys were returned. Even though individuals were encouraged to make any comments about the clarity, comprehensibility, and any problem areas of the survey questionnaire, no comments were made on any of the 22 surveys returned. Analysis of the twenty-two returned surveys did not reveal any problems. Some combat workload items were revised in accordance to survey comments made by pilots attending AFIT.

Population

In an effort to answer the main research question and investigative questions introduced in chapter one, pilots who had previously participated in combat, or flown in a high-threat environment in A-10, B-52, C-130, F-15, F-16, and KC-135, were surveyed.

These aircraft types were selected for several reasons. First, this listing contains aircraft which were used widely by the U.S. Air Force at the time of the survey. Including active Air Force, Air National Guard, and Reserve Units' inventories, there were 274 A-10/OA-10s, 85 B-52s, 878 C-130s, 529 F-15s, 859 F-16s, and 645 KC-135s flying in the U.S. Air Force as of June 1997 (USAF Aircraft Fact Sheets, 1997: 1). Therefore, flyers of these aircraft represent a good portion of USAF pilots. Second, each aircraft has different operational role and aircrew capacity requirement. Studying different aircraft types should give insights for a variety of cockpit workload assessments. Finally, all of the listed aircraft types were used in the Operations Desert Shield and Desert Storm. These aircraft flew several day- and night-time missions, and influenced the outcome of the war greatly.

The total number of pilots currently flying each aircraft is listed in the table below (HQ AFPC/DPAO, 1997: 2).

Table 3-1. Actively Flying USAF Pilots

Aircraft	Total number Actively Flying
A-10	352
B-52	203
C-130	833
F-15	555
F-16	1084
KC-135	1157

Sample

The sampling method used in the study is proportionate stratified sampling. Most populations can be segregated into several mutually exclusive subpopulations, or strata. The process by which the sample is constrained to include elements from each category is called *stratified random sampling* (Cooper and Emory, 1995: 221). The sample from each stratum, or aircraft type, was drawn such that it was proportionate to the stratum's share of the population. Proportionate stratified sampling is reported to have higher statistical efficiency over simple random sampling (Cooper and Emory,1995: 221).

Three reasons for a researcher to choose stratified random sampling are (1) to increase a sample's statistical efficiency, (2) to provide adequate data analyzing the various subpopulations, and (3) to enable different research methods and procedures used in different strata (Cooper and Emory, 1995: 221). In this study, proportionate stratified sampling was used to achieve the first two goals.

Initially, sampling plan requirements were based on a confidence interval of 90% to determine the sample size of each aircraft stratum. The sample size for each stratum was calculated based on the total number of pilot in each population group using the following formula (Krejcie and Morgan, 1970: 608):

$$n = \frac{z^2 N x 0.25}{((1-\alpha)^2 x(N-1)) + (z^2 x 0.25)}$$

where

n = sample size required

N = total population size

α = precision or confidence level desired (.10)

z = different factor for each confidence level (1.6449)

Table 3-2 presents the initial sampling plan and the number of surveys to be distributed for each aircraft type. Assuming a 56% return rate (the rate of a previous research AFIT master's thesis survey by Star and Welch (1991), which included the same sample strata and similar yet more questions), the number of surveys to be mailed was calculated as shown in the last column of the table. Table 3-3 presents the actual number of surveys mailed, and the final numbers of surveys responses received

The ATLAS database of AFPC located on a mainframe computer at Kelly AFB, San Antonio, TX was used to retrieve samples from each stratum based on pilots' Air Force Specialty Codes (AFSC) by HQ ACC/DPO and AMC/DPI. Table 3-4 presents the list of specialty codes used in sample generation process by Major Commands' Personnel Offices. In addition to AFSC, the selection criteria included the pilots assigned to ACC and AMC with combat flying hours greater than zero.

Table 3-2. Initial Sampling Plan and Survey Data

Aircraft	Required Sample Size	Number of Surveys to be mailed
A/AO-10	56 Pilots	100 Surveys
B-52	51	90
C-130	62	112
F-15	60	108
F-16	63	113
KC-135	63	113
Totals:	352 Pilots	632 Surveys

Table 3-3. Actual Survey Data

Aircraft	Number of Surveys Mailed	Number of Surveys Received
A/AO-10	112 Surveys	34 Surveys
B-52	120	41
C-130	133	32
F-15	88	31
F-16	121	42
KC-135	120	39
Totals:	694 Pilots	219 Surveys

Table 3-4. AFSC Data

Aircraft	AFSC
A/AO-10	1115N
B-52	1235C
C-130	1055B
F-15	1115B
F-16	1115Q
KC-135	1065C

A survey package, consisting of a cover letter, a survey questionnaire, an AFIT Form 11C, and a pre-addressed return envelope, was sent to each individual allowing adequate time to respond. The respondents were instructed to return the survey questionnaire and AFIT Form 11C in the pre-addressed enveloped.

Statistical Analysis of the Survey Data

The six investigative questions introduced in the first chapter, questions 2, 3a through 3d, and 4, were examined by analyzing the data gathered on SAS statistical analysis package. Responses to these six questions were analyzed to determine critical combat workload items in measuring workload in a combat environment, and a possible consensus of the relative priorities of combat workload items among USAF pilots. Data provided by answers to these particular questions should help draw conclusions about the overall research question: Is it possible to assess pilot workload in a high threat combat environment?

Survey questions 9 through 37 were intended to provide an answer to investigative question two, which asked, "Is it possible to determine, by surveying experienced pilots, what items would be most important in measuring workload in a high-threat environment?" The responses to each combat workload are summed and divided by the number of surveys returned to estimate an average numerical value to determine, overall, which combat workload items are found important by USAF pilots. The

following scale is used to determine the importance of overall ratings for combat workload items in assessing workload in high-threat environment.

If the average value for a particular combat workload item is:

1.599 or less, it is considered to be a dangerously important combat workload item;

1.600 - 2.599, it is considered as a distractingly important combat workload item;

2.600 - 3.599, it is considered as a moderately important combat workload item;

3.600 - 4.599, it is considered as a somewhat important combat workload item;

4.600 - 5.599, it is considered as a little or not important combat workload item;

5.600 or higher, it is considered as a not applicable combat workload item.

The combat workload items are presented in separate tables in Chapter IV depending on their importance category.

Survey questions 9 through 37were also intended to provide an answer to investigative question two, which asked, "What do pilots of different aircraft type believe are the critical items that would increase their workload in a high threat combat environment?" The responses to each combat workload item are grouped by the aircraft type. Then average values for each combat workload item are calculated by dividing the summed values of a particular combat workload item by the number of the respondents from that particular aircraft type. The scale described above is used to draw conclusions about the importance of combat workload items for each aircraft in assessing the pilot workload in a high-threat environment. The listings of combat workload items based on

their importance in workload assessment grouped by the aircraft type are presented in separate tables in Appendix D.

A similar methodology is used to evaluate the responses to investigative question 3b, which asked, “Does the level of workload perceived by pilots change depending on the type of the mission flown?” In this case, however, grouping of combat workload items is based on the type of the mission flown. The listings of combat workload items based on their importance in workload assessment grouped by the mission type are presented in separate tables in Appendix D.

Responses to investigative question 3c, which asked, “Does the level of workload perceived by pilots of each type vary by the experience level of the pilots?” were computed in similar fashion. Disregarding the aircraft type, average combat workload items are grouped separately based on total flying hours, combat flying hours, and previous aircraft experiences of all pilots, excluding trainers. Rank is not considered as an experience criterion from the standpoint of flying experience. Occasionally, a captain might have more flight experience than a lieutenant colonel or a colonel. B-52, C-130, and KC-135 pilots with more than 200 hours of combat and 2,000 hours of total flying time, and with at least one previous aircraft qualification except training aircraft are considered as “experienced” pilots. Similarly, AO/A-10, F-15, and F-16 pilots with more than 100 hours of combat and 1,000 hours of total flying time, and at least one previous aircraft qualification other than training aircraft are considered as “experienced” pilots. Otherwise, pilots not meeting these criteria are considered as “inexperienced.” Combat workload items based on responses by both “experienced” and “inexperienced” pilots,

along with average rating and standard deviation values, are listed in the same table in Chapter IV.

Analysis of responses to investigative question 3d, which asked, "Is there a particular combat workload item that significantly possesses higher perception of workload by all pilots?" is based on the average value of each combat workload item. Mean values, calculated during the analysis of the data for the investigative question two, were compared among all combat workload items in terms of their lower and upper 95 percent confidence intervals. It was hypothesized that Threat Avoidance would be valued as the most important workload item. For this hypothesis to be true, there would be no other workload item whose upper and lower intervals coincided with those of Threat Avoidance.

Finally, to draw conclusions about investigative question four, which asked, "Is it possible to enumerate combat workload perceptions of a pilots overall, or those of pilots from different aircraft, depending upon their characteristic data?" a variable called CWL (Combat Workload) was used. CWL is a variable which measures the overall perception of in-flight workload on a combat mission. Overall CWL score for each individual is calculated as a summation of responses to significant combat workload items.

To determine significant combat workload items, Cronbach's alpha and a Principal Component analysis are performed on the twenty-nine combat workload items introduced through Questions 9 through 37. For these analyses the SAS statistical analysis software package is used. Cronbach's alpha is a correlation analysis that measures the internal consistency from one set of measures to another set of measures

(SAS Institute Inc., 1990: 213). Cronbach's alpha is used to secure the reliability estimates of the test items, and it has the most utility for multi-item scales at the interval level of measurement (Cooper and Emory,1995:155).

Principal Component Analysis is the most frequently approach used in item analysis. This method transforms a set of variables into a new set of variables or principal components that are not correlated with each other. These linear combinations of variables, called items, account for the variance in the data (Cooper and Emory, 1995: 538). By performing the Cronbach's alpha and the Principal Component Analysis, the appropriateness of the selection of combat workload items to make up the overall CWL score of individuals is assured. These calculations should also ensure that the CWL score measures the same item for each individual. In addition to individual CWL scores, overall average CWL scores for aircraft are determined for each aircraft. After performing one-way ANOVA procedure on significant independent variables such as the current aircraft flown, the mean CWL score for each aircraft is compared to the overall mean scores of each of the other aircraft at 95 percent confidence level using the Bonferroni procedure. The Bonferroni procedure compares the mean of different groups by using the t-distribution. By comparing means between aircraft group, conclusions about possible differences in perceptions of combat workload items between pilots groups can be reached.

By using the data gathered in personal characteristics section of the questionnaire as independent variables, a model is developed by stepwise regression routine. This

model is expected to predict the pilots' perception of combat workload items. The following questions are used as independent experience variables.

1. What is your current rank?

3. How many hours of flight experience do you have, excluding flight training ?

4. What is the current aircraft you are flying or the most recent aircraft you flew?

5. What other aircraft have you flown?

6. How many hours of flight experience do you have in combat?

8. What primary mission did you fly in combat?

48. Is the individual an experienced pilot? (The answer was determined based on the criteria explained previously.)

A similar attempt is made to develop for each aircraft a different model that can predict the combat workload item perceptions of pilots of that aircraft. The result of stepwise routine is a model containing only those independent variables with t values that are significant at the pre-determined alpha level. The alpha level for this research effort was set to .05, which provides a 95 percent confidence level.

Statistical Tests

The SAS statistical analysis package, Version 6.12, was used to performed the required analyses. The analyses performed consisted of determining frequency responses, computing means, computing the results of one-way Analysis of Variance and Bonferroni t-tests, computing result of paired t-tests, comparing the lower and upper 95

percent confidence levels of mean values, performing reliability analysis, and performing stepwise regression routine on demographics data.

Summary

In this chapter, the construction process of the survey and the pre-test procedure have been discussed. In addition, population and the sample size of each aircraft stratum were described. Furthermore, the chapter discussed the statistical analysis to conclude the answers to the investigative questions of the first chapter.

IV. Data Analysis

Chapter Overview

This chapter presents the data gathered from the respondents of the survey questionnaire (included in Appendix A). There are three sections to this chapter: personal characteristics, analysis of workload items, and analysis of Combat Workload (CWL) scores. Each section describes the data received from US Air Force pilots who participated in this survey. These sections also includes the discussion of unexpected or unusual facts about the data.

Personal Characteristics

Initially, it was intended to survey a sample size large enough to assure a 90% confidence level. Nevertheless, the number of surveys received did not meet the requirement for a 90% confidence level on any of the aircraft types. Of 694 surveys distributed, only 219 were returned, for a return rate of 31.6%. Figure 4-1 illustrates the responses received from individuals grouped by the aircraft type.

The low return rate could be explained as follows: (1) no preliminary notification was made to individuals about the survey package they would receive; (2) no follow-up letters were sent to individuals to remind them of the importance of their participation in the research effort; and (3) no return postage was furnished on the pre-addressed return envelopes. These precautionary methods of improving the survey returns were not able

to be accomplished due to time and budgetary constraints. Cooper and Emory (1995) note that follow-ups, preliminary notification, and concurrent techniques such as questionnaire length, survey sponsorship, return envelopes, postage, personalization, cover letters, anonymity, size and color, money incentives, and deadline dates are the three important variables for improving the return rate of survey responses (Cooper and Emory, 1995: 283).

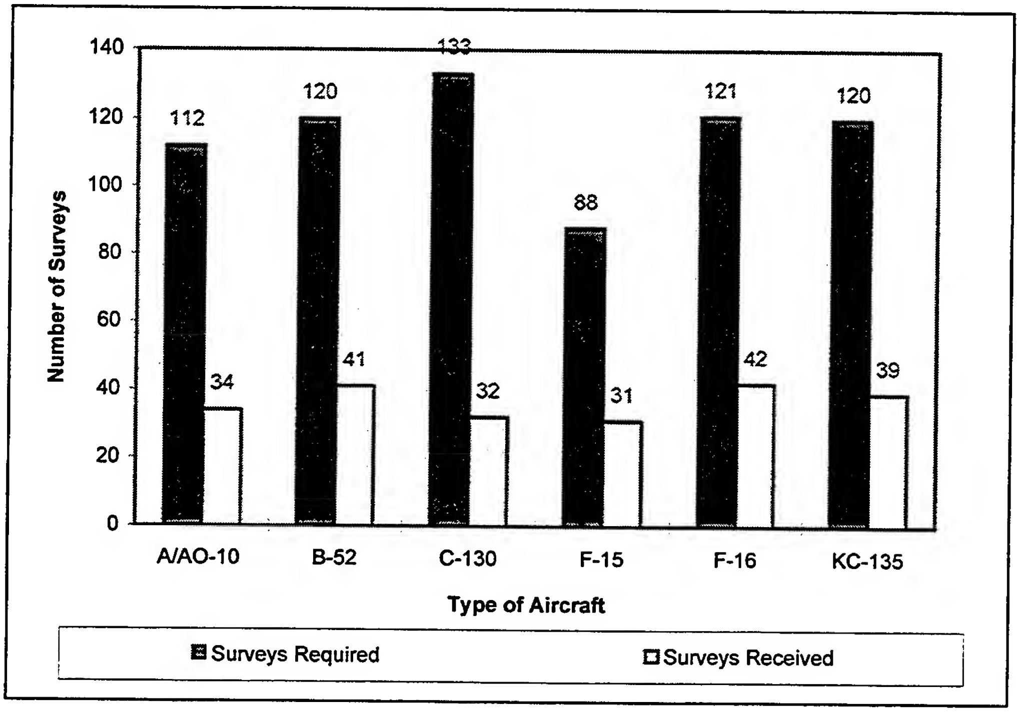

Figure 4-1. Survey Returns

Thirty-six of the survey packages sent were returned to sender because the addressees out-processed to a different unit. One of the individuals who returned the package was not a pilot. Six of the pilots who responded were flying different aircraft

from those which were included in the survey. These responses were not included in the data set. From the figures mentioned in this paragraph, it might be quite possible that ATLAS database used in sample generation did not contain the latest records about USAF pilots flying the types of aircraft researched.

Figure 4-2 illustrates the percentages of the surveys responses grouped by aircraft types. The figure presents the respondents' share in the data set used in the statistical analysis. Figure 4-3 presents the current military rank distribution of the respondents.

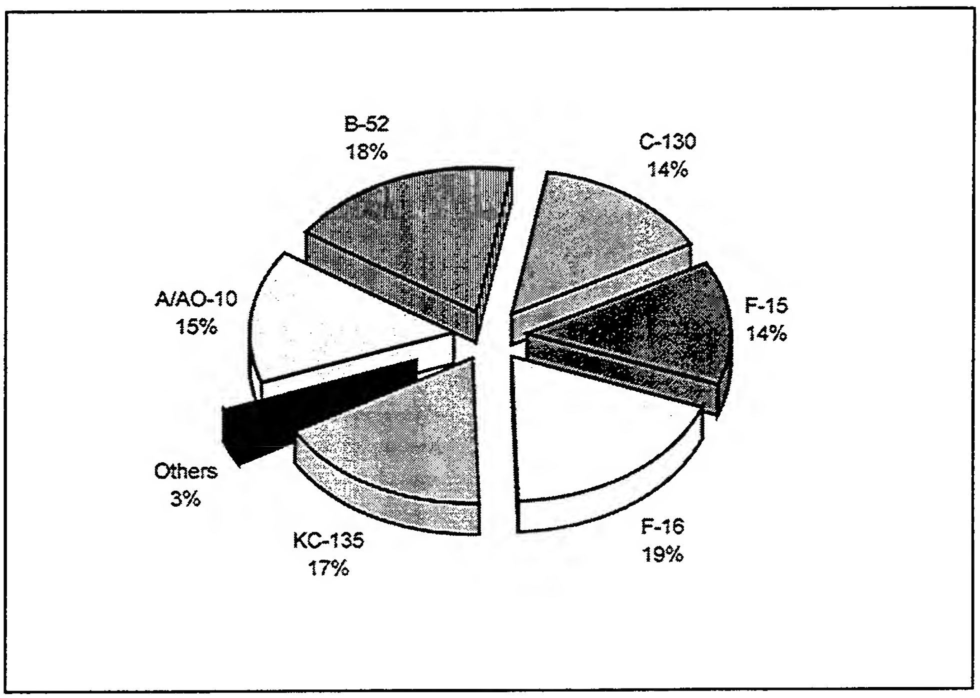

Figure 4-2. Percentages of Returned Surveys for Each Aircraft

Almost 50 percent of all respondents held the military rank of captain. Pilots with the military rank of major yielded 36% of all respondents. Pilots with the military ranks

of captain and major constituted the majority of the data. As 1st or 2nd lieutenants or captains of recent major conflicts such as Operation Desert Storm or Operation Deny Flight, the majority of the survey sample participated in those conflicts.

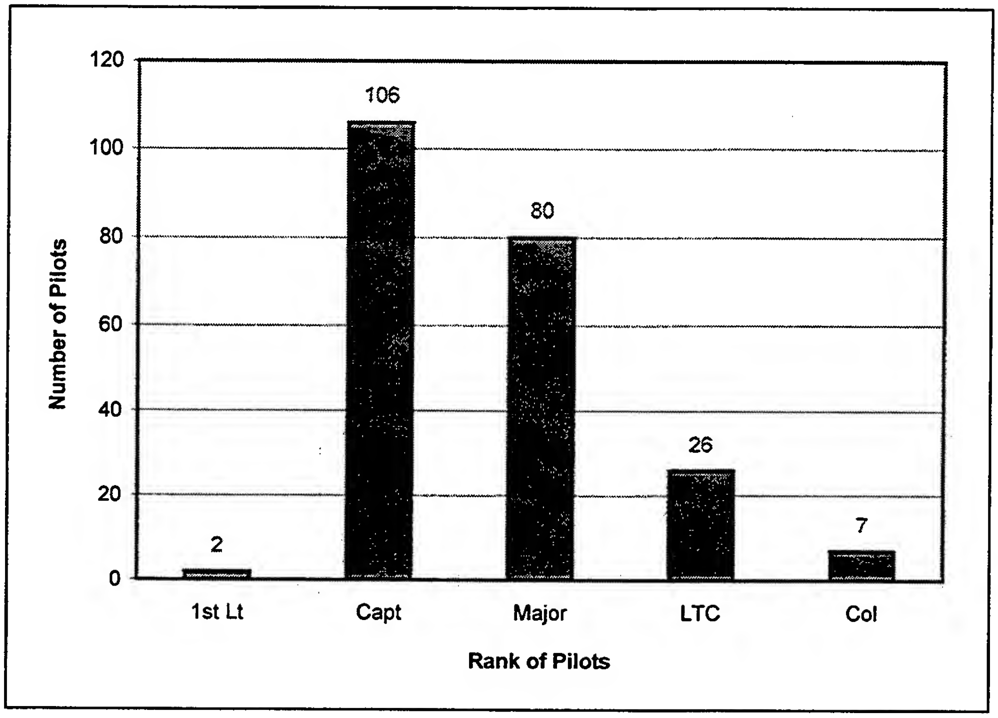

Figure 4-3. Current Rank Distribution of Pilots

None of the respondents was female, even though survey packages were sent to several female pilots. Female pilots first attended flight school in 1977. They had not been accepted for training in fighter aircraft until July of 1993. According to demographic data released by HQ AFPC, as of 28 April 1997, 342 female pilots serve in the United States Air Force, or 2.32 percent of the pilot force. For this reason, gender

related differences about the pilots' perception of workload assessment could not be analyzed.

The remainder of the data on personal characteristics reveals information about the experience level and the recent aircraft qualifications of the pilots. The experience and qualification areas measured were: (1) the total amount of flight hours accumulated on a USAF aircraft other than training models; (2) the total amount of flight hours accumulated in combat; and (3) the number of the recent military aircraft types that respondents were qualified to fly. The personal characteristic data contain information about the types of missions which pilots had flown recently.

Figures 4-4 and 4-5 depict the total amount of flying hours in the six aircraft types researched excluding UPT flying hours. A scale from *less than 500 hours* to *more than 3,000 hours* with 500-hour bin width was used. However, the total amount of flying hour data from six different aircraft shows that the scale arrangement with 500-hour bin width was inappropriate for B-52, C-130, and KC-135 aircraft. The total amount of flying hours data for these aircraft, illustrated in Figure 4-5, is skewed to the right. In these aircraft, unlike AO/A-10, F-15 and F-16 aircraft, greater flying time is accumulated in one sortie. Longer duration missions in these aircraft types allow the pilots to accumulate more flying hours in a shorter period of time. In classifying the total amount of flying hours, two different aircraft groups are used, "heavy" and "light." "Heavy" aircraft consist of B-52, C-130, and KC-135 aircraft while "light" aircraft include AO/A-10, F-15 and F-16 aircraft. From the same perspective, the "experienced" and "inexperienced" criteria were established for pilots from each aircraft group. "Light" pilots with less than

1000 hours of total flying time were considered "inexperienced"; similarly, "heavy" pilots with less then 2,000 hours of total flying time were considered "inexperienced." A one to two ratio between inexperience and experience criteria in terms of flying hours were determined according the ratio of average duration of sorties between each aircraft group. Based on the classification criteria above, approximately 93 percent of "light" pilots were "experienced" while 98 percent of "heavy" pilots were experienced.

Similarly, Figures 4-6 and 4-7 the illustrate total amount of pilot flying hours accumulated in combat. To collect the total amount of combat flying hours accumulated in each type of the aircraft, a smaller scale was used. The scale included a "none" option, and ranged from *equal or less than 100 hours* to *more than 500 hours* with bin width of 100 hours.

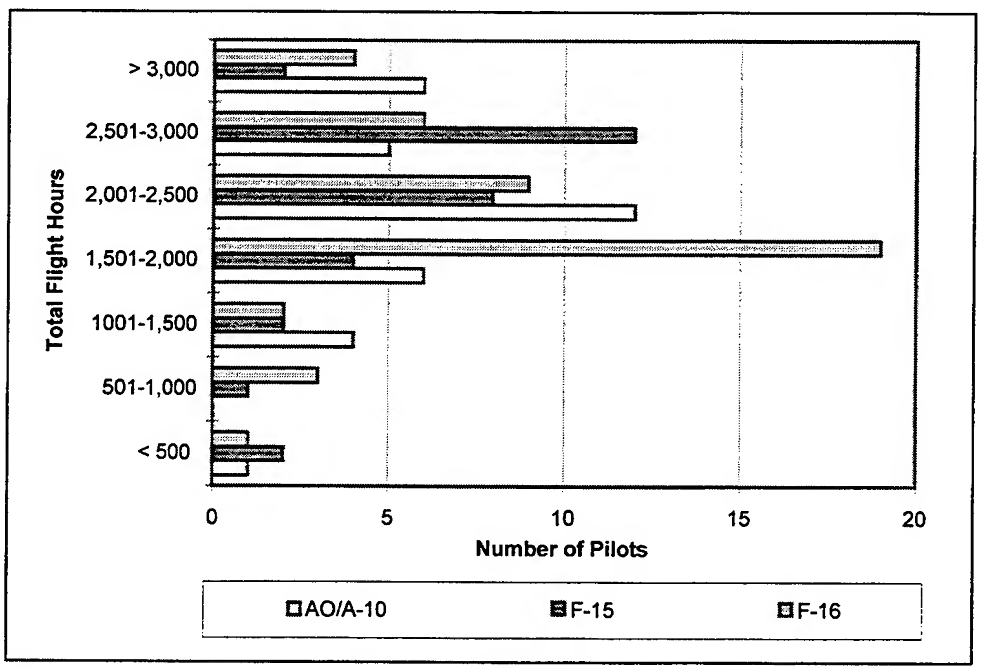

Figure 4-4. AO/A-10, F-15, and F-16 Pilots' Total Flying Hours

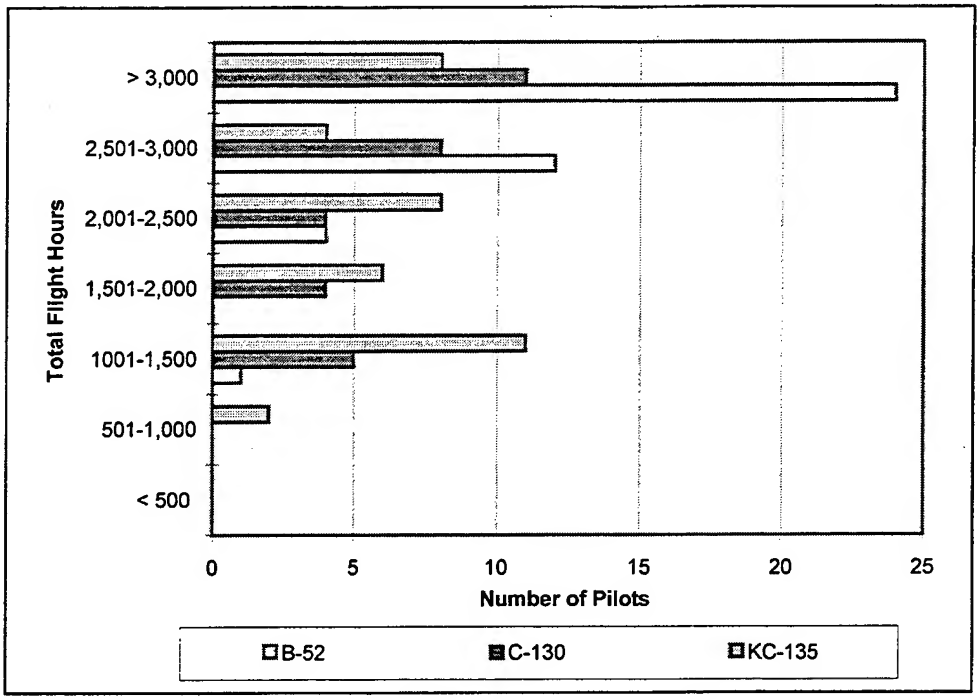

Figure 4-5. B-52, C-130, and KC-135 Pilots' Total Flying Hours

Combat experience is an important measure for the purpose of the study. As mentioned in the second chapter, this study surveyed USAF pilots' perception of pilot workload assessment in combat or in a high-threat environment. Sample generation focused on subjects who had logged at least one combat flying hour. "Inexperienced" criteria limits for "light" and "heavy" were established as equal or less than 100 hours and 200 hours, respectively. According to these criteria, approximately 54 percent of "light" pilots and 11 percent of "heavy" pilots were "experienced" in combat flying hours category. It should be noted that percentages of "experienced" pilots of each general aircraft classification are similar when total amounts of flying hours are compared; however, those differ considerably when comparing total amounts of combat flying

hours. For both classifications of aircraft, the total amount of combat flying hours data is skewed to the left. When Figures 4-6 and 4-7 are examined, combat flight hours distributions of "light" and "heavy" pilots are similar. It might appear that the 1:2 ratio between combat flying hours of "light" and "heavy" pilots is not reflected in Figures 4-6 and 4-7. This apparent lack of difference could be due to fact that "light" pilots are scheduled for combat missions more frequently in comparison with the "heavy" pilots in the same regional conflict. Frequently scheduled combat missions could allow "light" pilots to accumulate similar amounts of combat flying hours in a shorter time compared to "heavy" pilots.

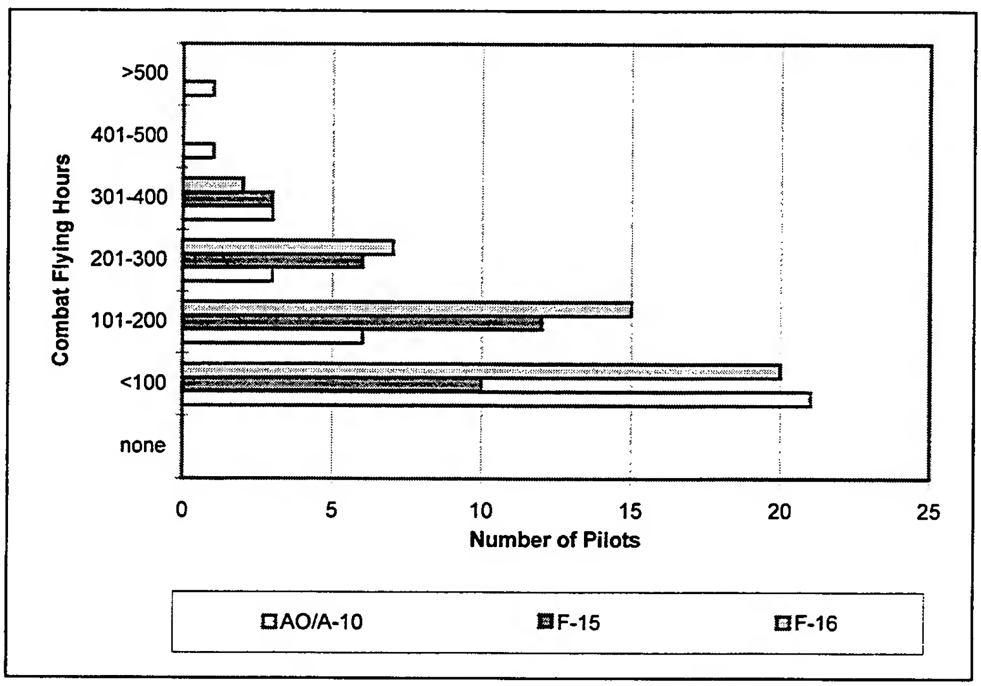

Figure 4-6. AO/A-10, F-15, and F-16 Pilots' Combat Flying Hours

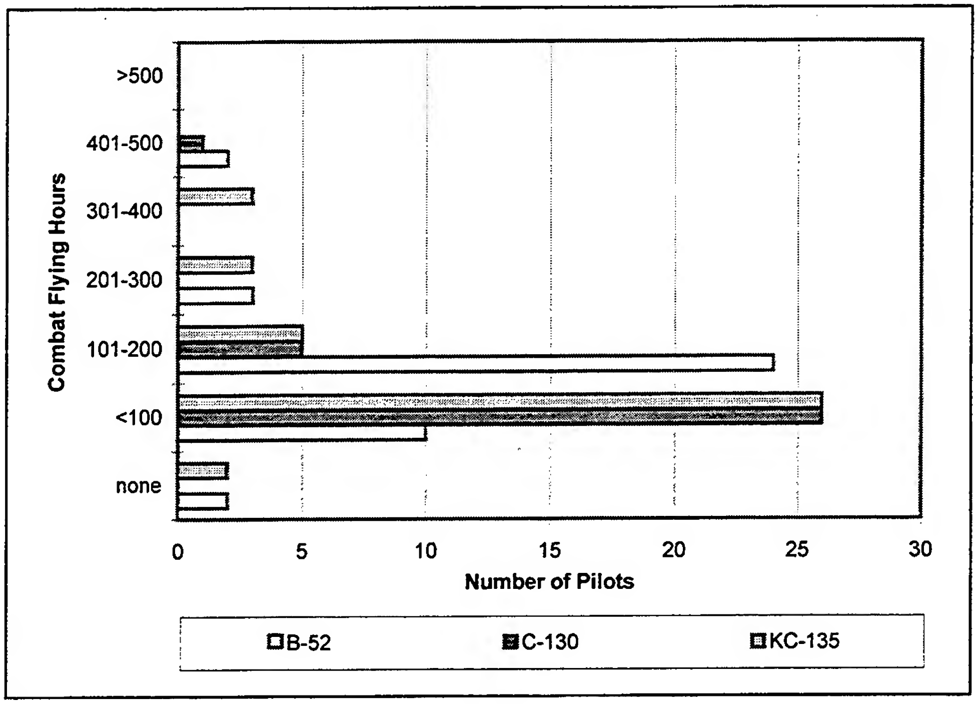

Figure 4-7. B-52, C-130, and KC-135 Pilots' Combat Flying Hours

Figures 4-8 and 4-9 illustrate the previous aircraft experiences of pilots of each type. The previous aircraft experience data were also presented separately for "light" and "heavy" pilots. A clear presentation is achieved when aircraft are divided into two groups.

Data Question 5 of the survey shows that over 60 percent of all pilots had no previous operational aircraft experience, excluding all types of military training aircraft. At least one previous operational aircraft was flown by 40 percent of all pilots, while 5 percent and 1 percent of them had experience in two and three previous operational aircraft, respectively. Table 4-1 presents the detailed percentages of previous aircraft experience of pilots in each aircraft type. Based on the pertaining data, almost 37 percent of all pilots flew at least one operational aircraft previously.

When the three criteria for "experience," those of total flying hours, combat flying hours, and previous aircraft experience, are considered simultaneously, "experienced" pilots yielded only 13.7% of the sample. Of 30 "experienced" pilots, 25 were "light" pilots while the remaining five pilots were flying "heavy" aircraft.

Finally, Figure 4-10 presents the percentage of the recent combat missions flown by all pilots. The data indicates that each combat mission had a relatively equal share. This is mainly because six aircraft types selected for the study perform a wide variety of missions, and these aircraft represent a good portion of USAF aircraft inventory.

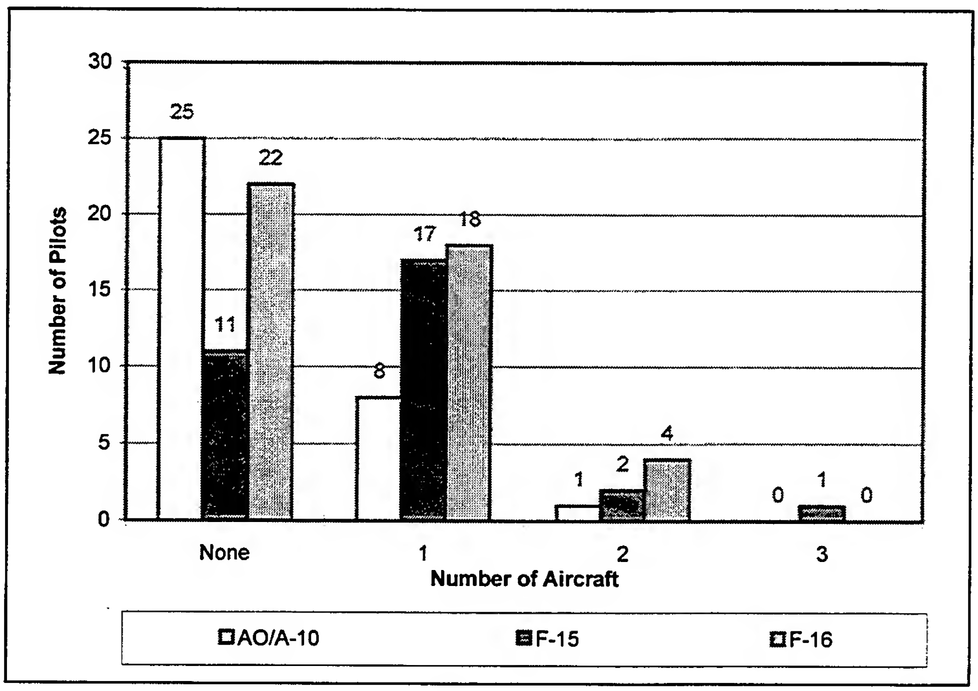

Figure 4-8. AO/A-10, F-15, and F-16 Pilots' Previous Aircraft Experiences

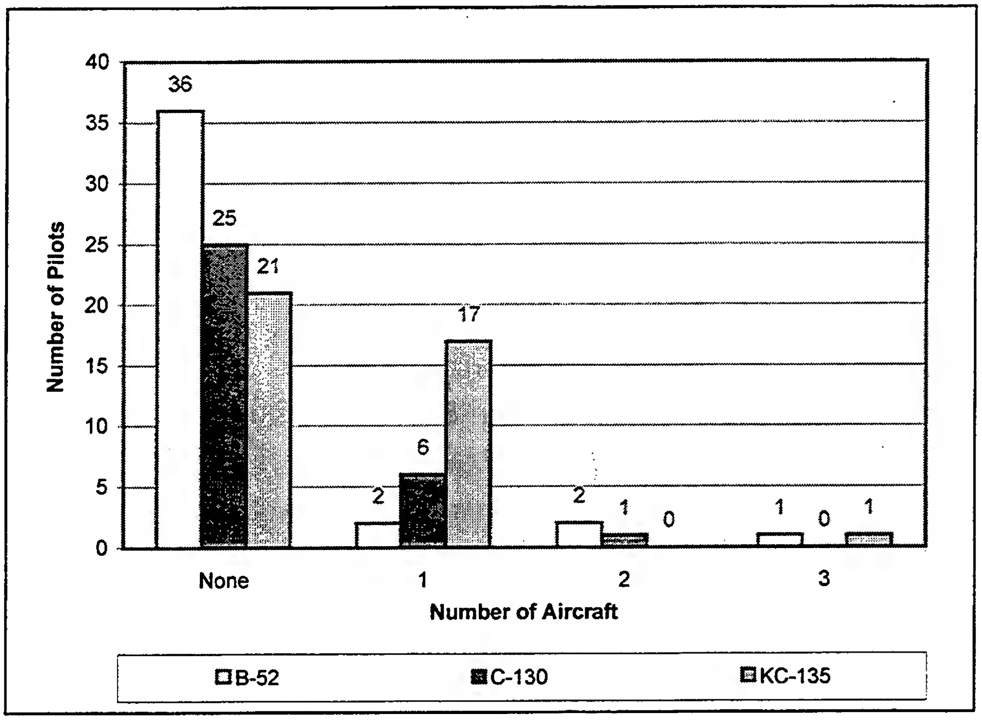

Figure 4-9. B-52, C-130, and KC-135 Pilots' Previous Aircraft Experiences

Table 4-1. Previous Experiences of Pilots by Current Aircraft Type

	Number of Aircraft Flown Previously				
Current Aircraft	None	1	2	3	At least 1
AO/A-10	73.4%	23.5%	2.9%	- %	26.5%
B-52	87.8	4.9	4.9	2.4	12.2
C-130	78.1	18.8	3.1	-	21.9
F-15	35.5	54.8	6.5	3.2	64.5
F-16	50.0	40.9	9.1	-	50.0
KC-135	53.8	43.6	-	2.6	46.2
Overall	63.3%	30.8%	4.5%	1.4%	36.7%

Furthermore, almost all aircraft types have different models and versions, resulting in several different uses in combat. For instance, AO-10 are flown on rescue missions, as well as on Close Air Support (CAS) missions.

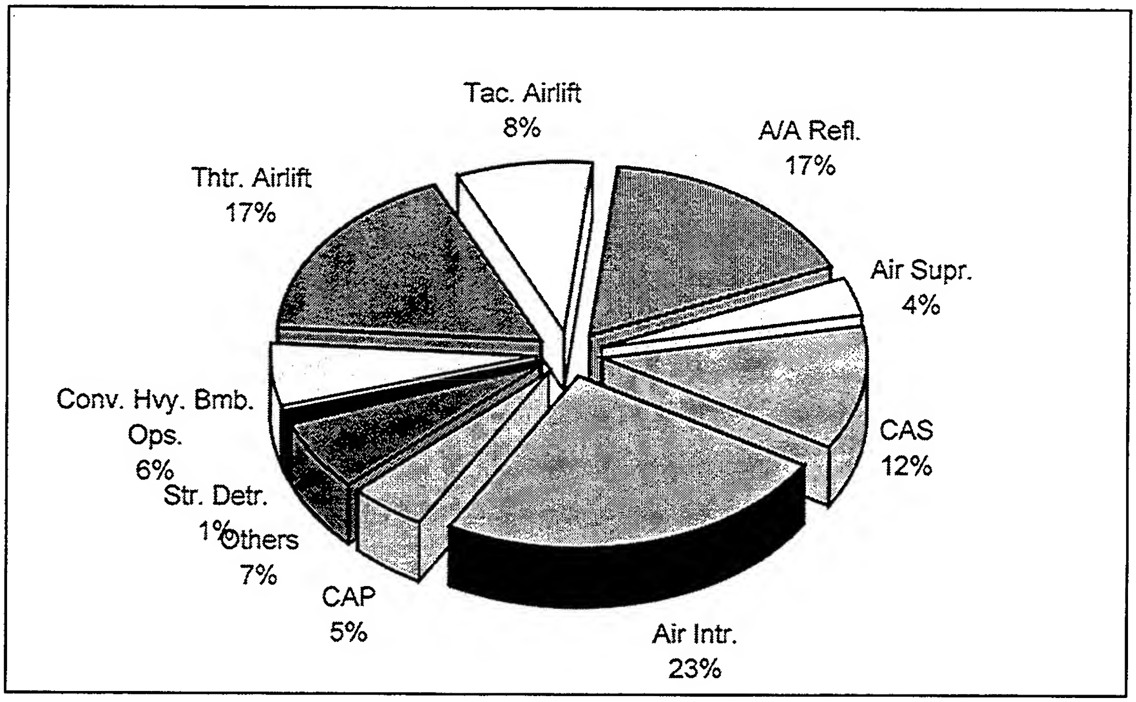

Figure 4-10. Recently Flown Combat Missions

Abbreviations:

Str. Detr.: Strategic Deterrence
Conv. Hvy. Bmb. Ops.: Conventional Heavy Bombing Operations
Thtr. Airlift: Theater Airlift
Tac. Airlift: Tactical Airlift
A/A Refl: Air to Air Refueling
Air Supr.: Air Superiority
CAS: Close Air Support
Air Intr.: Air Interdiction
CAP.: Combat Air Patrol

Despite the large span of missions flown by all aircraft, close investigation of the data reveals that certain mission types dominate the aircraft types in which these missions are flown. When the data were grouped by aircraft type, the following inferences were made. Of 33 AO/A-10 pilots, 25 flew CAS missions in combat. Thirty-seven of 41 B-52 pilots flew Conventional Heavy Bombing Operations in combat. Nearly half of the

C-130 pilots flew Theater Airlift missions while the other half flew Tactical Airlift missions in combat or a high-threat environment. Of 31 F-15 pilots surveyed, 24 flew Air Interdiction missions. The F-16 is the only aircraft type whose mission type is highly diverse. However, half of the pilots of this type flew Air Interdiction missions. Almost all KC-135 pilots flew Air to Air Refueling missions in combat.

Overall, examination of personal characteristics of pilots surveyed reveals that the subjects of this study were highly experienced. Demographic analysis indicates that the sample of this study represents a good portion of the experienced USAF pilot population. The subjects of this study are possibly more experienced than the majority of aviators in the U.S. Air Force. Almost all subjects have more than 1000 hours of flying time on a tactical aircraft. Furthermore, nearly all pilots accumulated some combat flying time, while the majority of them logged over 100 hours of combat flying time. A great portion of the subjects possess a military rank of captain or higher. More than one third of all subjects were previously qualified in at least one type of aircraft. Last, subjects of this study have recently flown various types missions in combat. The high level of experience of subjects, both in peacetime and wartime, adds credibility to findings of this research as well as to the comments of pilots who participated in this study.

Analysis of Workload Items

To answer the major research question, several investigative questions were asked in the first chapter of the study. One of the questions asked if it is possible to determine,

by surveying experienced pilots, what items would be most important in measuring workload in a high-threat environment. As explained in the second chapter, to draw conclusions about the particular investigative questions, questions 9 through 37 in the survey questionnaire were asked. Each question specified a workload item, which was common to all aircraft types. Pilots were directed to evaluate each workload item in terms of the degree to which it was likely to increase the pilot workload in a combat environment, using a five-point Likert scale. Because all tasks do not apply to all six aircraft types surveyed, a "not applicable" choice was included in the choices.

Responses to each workload item were summed and divided by the number of surveys returned to estimate an average numerical value to determine overall which workload items were found important by USAF pilots. The following scale was used to determine overall workload items to conclude that they were important in assessing workload in high-threat environment.

Analysis of All Combat Workload Items

First, the ratings for combat workload items from pilots of all aircraft types were evaluated together. The listings of workload items based on their importance in workload assessment in combat or near combat high threat environment are given in Tables D-1 through D-3 (in Appendix D). Combat workloads in each category are listed in descending order of importance within the particular category. A workload item with a lower mean value indicates a higher level of perception. Should two or more combat workload items be rated equally on the average, the one with less standard deviation

value was listed first. When two or more combat workload items had the exact mean and standard deviation values, the one with the smallest range of ratings was listed first. Even if the range values happened to be the same, then the workload item that appeared first in the survey questionnaire was listed first.

Overall, no combat workload items are found to be "dangerously" important in workload assessment. Although 24 out of 29 combat workload items were rated by at least one pilot as likely to increase pilot workload "dangerously" in combat, resulting in possible extreme delays in the task currently being performed or unsafe situation or mission failure, on the average none of those items is found to be "dangerously" important. Likewise, no combat workload items could be concluded to be of "little" or "no" importance in workload assessment, according to the ratings of all pilots. Yet, pilots rated several combat workload items as likely to increase pilot workload a little or not at all. Furthermore, no combat workload items were found to be not applicable among all aircraft. It might be implied that the selection of the listing of twenty-nine combat workload items was performed properly to represent common tasks on a combat mission. Nevertheless, all 29 workload items were evaluated as "not applicable" by at least one pilot who participated in the research.

Based on the mean value of ratings of all pilots surveyed, Threat Avoidance was the combat workload item with the highest level of perceived workload, followed by In-flight Emergency. These combat workload items were only the two which were determined to be likely to increase pilot workload "distractingly" in combat. Eleven combat workload items were found to be likely to increase pilot workload "moderately."

The remaining sixteen workload items were believed to cause "some" increase in in-flight workload. Among all items, Air Refueling Operations was found to be the least important combat workload item from the stand point of in-flight workload assessment.

Question 37a of the survey questionnaire asked pilots to make any additions to the 29 combat workload items. Four pilots, who selected to comment on the question, specified the usage of night sighting devices and Nuclear-Biological-Chemical (NBC) protection gear as other items that increase pilot workload in a high-threat environment. Their comments deserve attention and should be considered by future researchers of in-flight workload assessment.

When all combat workload items' ratings of pilots from six aircraft types are examined together, it is found that the worst workload scenario exists if an in-flight emergency occurs while avoiding an enemy threat. This scenario applies to all types of aircraft regardless of the type of missions flown.

Analysis of Combat Workload Items by Aircraft

In this area, data were grouped by aircraft type and analyzed in the same manner. Table 4-2 presents those combat workload items which pilots rated as likely to "distractingly" increase pilot workload in combat, segregated by aircraft type. Tables D-4 through D-28 of Appendix D list combat workload items at varying levels of perceived pilot workload in combat, based on the average ratings of pilots from each aircraft type. As reported earlier in Chapter 3, the study intended to identify some in-flight tasks that might increase pilot workload "dangerously." As with overall ratings, surprisingly, no

combat workload items were evaluated as "dangerously" important when the pertaining data were analyzed within each aircraft type. Therefore, evaluation of "dangerously" important workload items in each aircraft type was not possible. To save time and effort in analysis, examination of combat workload items found to increase pilot workload "moderately," "somewhat," or "a little" or "not," and those concluded to be "not applicable" for the particular aircraft type are not listed in tables in this section. Instead, they are reported only in the text.

AO/A-10. Of 29 combat workload items, 23 items were rated as likely to increase pilot workload "dangerously" by at least one of 34 AO/A-10 pilots surveyed; however, no combat workload item was concluded to be "dangerously" important in pilot workload assessment by all AO/A-10 pilots. Five combat workload items found to be "distractingly" important among AO/A-10 pilots in workload assessment are listed in Table 4-2. Among these five, Threat Avoidance was rated as the most important combat workload item. AO/A-10 pilots rated 14 combat workload items, which are listed in Table D-5, as "moderately" important items in workload assessment. "Moderately" important items consisted of Night Operations, Night Low Level Navigation, Equipment Degradation, Fatigue, Target Acquisition, Threat Acquisition, Threat Detection, Unfamiliar Terrain, Terrain Avoidance or Terrain Following, Crew Incapacitation, Low Level Operation, Shifting Attention to Targets of Opportunity, Command and Control, and Management of TOT. Based on the average values of ratings, the following nine workload items were found to be "somewhat" important (Table D-6).

Table 4-2. Distractingly Important Combat Workload Items by Aircraft Type

Aircraft	Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
AO/A-10	1. Threat Avoidance	1.9118	0.8658	1.0000	3.0000
	2. In-flight Emergency	2.0588	0.6938	1.0000	4.0000
	3. Adverse Weather	2.2941	0.9701	1.0000	5.0000
	4. Aircraft Maneuvering	2.3529	1.5116	1.0000	5.0000
	5. In-flight No-notice Mission Changes	2.5882	0.7437	1.0000	4.0000
B-52	1. Crew Incapacitation	1.7692	1.0378	1.0000	5.0000
	2. Threat Avoidance	1.8974	0.5522	1.0000	3.0000
	3. Fatigue	2.0513	0.9163	1.0000	4.0000
	4. Night Low Level Navigation	2.3077	1.0552	1.0000	6.0000
	5. In-flight Emergency	2.4103	0.7152	1.0000	4.0000
	6. Aircraft Maneuvering	2.4103	1.0442	1.0000	4.0000
C-130	1. Threat Avoidance	2.2500	0.8032	1.0000	4.0000
	2. In-flight Emergency	2.5000	1.1359	1.0000	5.0000
	3. Adverse Weather	2.5625	1.0453	1.0000	5.0000
	4. Crew Incapacitation	2.5625	1.4797	1.0000	6.0000
	5. Fatigue	2.5938	0.9456	1.0000	4.0000
F-15	1. In-flight Emergency	2.1613	1.0984	1.0000	6.0000
	2. Crew Incapacitation	2.2258	1.9098	1.0000	6.0000
	3. Threat Avoidance	2.2903	0.7829	1.0000	4.0000
F-16	1. In-flight Emergency	2.2500	0.9675	1.0000	5.0000
	2. Threat Avoidance	2.3636	1.2025	1.0000	6.0000
KC-135	1. Crew Incapacitation	2.3590	1.5129	1.0000	6.0000
	2. In-flight Emergency	2.4359	0.9402	1.0000	5.0000
	3. Threat Avoidance	2.5385	1.0475	1.0000	5.0000

They are, in descending order of importance: Managing Radio Communication, Responding to Ground/Air Controllers Instructions, Munitions Deployment, Visual Orientation, Formation Responsibilities, Mission Planning, Type of Drop, Monitoring Flight Instruments, and Refueling Operations. On the average, AO/A-10 pilots rated Crew Coordination as the least important combat workload item, as "a little" or "not" important, due to fact that they fly mostly single-seat models (Table D-7). No combat workload items were evaluated as "not applicable" on the average, although six out of 29 workload items are rated as "not applicable" by one or more AO/A-10 pilots.

B-52 . Though 17 combat workload items were rated as likely to increase pilot workload "dangerously" by one or more B-52 pilots surveyed, no combat workload item was concluded to be "dangerously" important in pilot workload assessment. Six combat workload items were found to be "distractingly" important by 40 B-52 pilots, and they are listed in Table 4-2. Among all items, Crew Incapacitation was rated as the highest important combat workload item. B-52 pilots' average ratings identified 14 combat workload items presented in Table D-9 as "moderately" important items in combat workload assessment. The fourteen "moderately" combat workload items, in descending order of importance, were In-flight No-notice Mission Changes, Adverse Weather, Terrain Avoidance or Terrain Following, Night Operations, Equipment Degradation, Unfamiliar Terrain, Low Level Navigation, Maintaining Situational Awareness, Threat Detection, Crew Coordination, Target Acquisition, Managing Radio Communication, Command and Control, and Formation Responsibilities. Among these workload items, Target Acquisition and Managing Radio Communication demonstrated comparable

ratings as important combat workload items. According to the average rating values, nine B-52 "somewhat" important combat workload items are, in the descending order of importance: Responding to Ground or Air Controllers Instructions, Management of TOT, Visual Orientation, Munitions Deployment, Type of Drop, Shifting Attention to Targets of Opportunity, Monitoring Flight Instruments, Refueling Operations, and Mission Planning (Table D-10). On the average, B-52 pilots chose Mission Planning as the least important combat workload item. No combat workload item was found to be "a little" or "not" important item, and there were no "not applicable" items. However, each of 10 different combat workload items was rated as "not applicable" by at least one B-52 pilot.

C-130. Despite the fact that 21 combat workload items were evaluated as likely to increase pilot workload "dangerously" by a minimum of one C-130 pilot, no combat workload item was considered as "dangerously" important overall in pilot workload assessment. Based on the evaluation of 32 C-130 pilots, five combat workload items were identified as "distractingly" important, which are presented in Table 4-2. Threat Avoidance was evaluated as the most important combat workload item. The following items, also listed in Table D-12, are fifteen combat workload items evaluated as "moderately" important items in workload assessment according to C-130 pilots' average ratings: Aircraft Maneuvering, In-flight No-notice Mission Changes, Command and Control, Terrain Avoidance or Terrain Following, Maintaining Situational Awareness, Night Low Level Navigation, Managing Radio Communication, Threat Detection, Equipment Degradation, Low Level Navigation, Unfamiliar Terrain, Formation Responsibilities, Night Operations, Mission Planning, and Crew Coordination. C-130

pilots' average ratings specified Visual Orientation, Target Acquisition, Management of TOT, Responding to Ground Airborne Controller Instructions, Monitoring Flight Instruments and Type of Drop as the six "somewhat" important combat workload items (Table D-13). Shifting the Attention to Targets of Opportunity was valued as of "a little" or "no" importance (Table D-14). The measuring scale used in the survey was successful in detecting Munitions Deployment and Refueling Operations as "not applicable" to C-130 combat operations, because most C-130 aircraft are not equipped with munitions deployment or air-to-air refueling systems (Table D-15).

F-15 . Evaluations of 31 F-15 pilots revealed that no combat workload item was considered as "dangerously" important. On the other hand, thirteen combat workload items were rated as likely to increase pilot workload "dangerously" by one or more F-15 pilots. Three workload items, presented in Table 4-2, were measured as "distractingly" important. Their highest perceived combat workload item choice was In-flight Emergency followed by Crew Incapacitation. Threat Avoidance was rated as the third most important combat workload item. F-15 pilots' average ratings determined nine combat workload items presented in Table D-17 as "moderately" important items in combat workload assessment. They were Aircraft Maneuvering, Fatigue, Equipment Degradation, Adverse Weather, In-flight No-notice Mission Changes, Terrain Avoidance or Terrain Following, Shifting Attention to Targets of Opportunity, Maintaining Situational Awareness, and Threat Detection. According to the average rating values, the remaining 15 combat items were found to be "somewhat" important when assessing workload. They are, in descending order of importance, Target Acquisition, Night

Operations, Low Level Navigation, Night Low Level Navigation, Command and Control, Unfamiliar Terrain, Munitions Deployment, Visual Orientation, Formation Responsibilities, Mission Planning, Managing Radio Communication, Management of TOT, Type of Drop, Responding to Ground or Airborne Controller Instructions, Monitoring Flight Instruments, Crew Coordination, and Air Refueling Operations (Table 4-18). On the average, F-15 pilots' choice of the least important combat workload item was Air Refueling Operations. No combat workload item was found to be "a little" or "not" important item at all. Although almost two thirds of the combat workload items was rated as "not applicable" by at least one pilot, none was valued as "not applicable" on the average.

F-16. Although 13 combat workload items were rated as likely to increase pilot workload "dangerously" by one or more F-16 pilots surveyed, no combat workload item was concluded to be "dangerously" important in pilot workload assessment on the average. Only In-flight Emergency and Threat Avoidance were valued as "distractingly" important by 44 F-16 pilots, the former rated as the most important. The two "distractingly" important workload items are presented in Table 4-2 along with the mean value scores. Upon examination of F-16 pilots' ratings, twelve combat workload items were found as "moderately" important items in combat workload assessment. Twelve combat workload items are, also listed in Table D-20, Adverse Weather, In-flight No-notice Mission Changes, Fatigue, Aircraft Maneuvering, Equipment Degradation, Night Operations, Threat Detection, Night Low Level Navigation, Target Acquisition, Shifting Attention to Targets of Opportunity, Maintaining Situational Awareness, and Crew

Incapacitation. Based on the average rating values, thirteen F-16 "somewhat" important combat workload items are, in descending order of importance, Unfamiliar Terrain, Low Level Navigation, Terrain Avoidance or Terrain Following, Munitions Deployment, Managing Radio Communications, Command and Control, Responding to Ground or Airborne Radar Controller Instructions, Management of TOT, Mission Planning, Formation Responsibilities, Monitoring Flight Instruments, and Type of Drop (Table D-21). Air Refueling was valued as a "little" or "not" important combat workload item on the average (Table D-21). Crew Coordination was rated as "not applicable" to F-16 aircraft due to fact that all F-16s, except training models, are single-seated fighter aircraft.

KC-135 . Fifteen out of twenty-nine combat workload items were rated as likely to increase pilot workload "dangerously" by at least KC-135 pilots surveyed, but no combat workload item was concluded to be "dangerously" important in pilot workload assessment on the average. Three combat workload items, which are found to be "distractingly" important by 39 KC-135 pilots, are listed in Table 4-2. Among all items, Crew Incapacitation was rated as the highest important combat workload item. Table D-25 presents six combat workload items, that KC-135 pilots valued as "moderately" important items in combat workload assessment. They are Fatigue, Adverse Weather, Equipment Degradation, In-flight No-notice Mission Changes, Formation Responsibilities, and Aircraft Maneuvering. According to the average rating values, twelve "somewhat" important combat workload items for KC-135s are, in descending order of importance, Command and Control, Maintaining Situational Awareness, Managing Radio Communication, Refueling Operations, Threat Detection, Crew

Coordination, Night Operations, Visual Orientation, Responding to Ground or Airborne Controller Instructions, Mission Planning, Unfamiliar Terrain, and Monitoring Flight Instruments (Table D-26). On the average, Terrain Avoidance or Terrain Following, Night Low Level Navigation, Management of TOT, and Shifting Attention to Targets of Opportunity are valued as "a little" or "not" important combat workload items (Table D-27). Target Acquisition, Type of Drop, and Munitions Deployment are found "not applicable" to KC-135 aircraft (Table D-28).

When Table 4-2 was reviewed closely, Threat Avoidance and In-flight Emergency were rated as likely to increase pilot workload "distractingly" in combat. Threat Avoidance was present in all aircraft types within the top three items, and it was rated highest in two aircraft types. In-flight Emergency was present in all aircraft listings within the top five combat workload items, and it was rated highest in two aircraft types. Other common combat workload items found "distractingly" important across aircraft types were Crew Incapacitation, Fatigue, Adverse weather, and Aircraft Maneuvering. Among these combat workload items, Crew Incapacitation was rated highest in two aircraft types. It was interesting to find that Fatigue was not considered as "distractingly" important item by fighter pilots; however, it was present in the listing of "distractingly" important combat workload items of B-52 and C-130 pilots who fly considerably longer missions. AO/A-10, B-52 and C-130 pilots rated more items as "distractingly" important than pilots of F-15, F-16, and KC-135 aircraft. Advanced technologies used in the latter group of aircraft might be a factor in the lower number of items in this category.

Overall, it might be concluded that, regardless of aircraft type, the worst scenario of pilot workload in combat exists when an in-flight emergency occurs while avoiding a known enemy threat. The same of degree of commonality was not observed when "moderately," "somewhat," "a little" or "not" important combat workload items were examined.

Analysis of Combat Workload Items by Missions Flown

In this analysis, data were grouped by missions most previously flown. The segregated data was analyzed as in the analysis of the data grouped by aircraft. Tables 4-3a and 4-3b present the combat workload items which pilots believe "moderately" increase combat workload by the most recent combat mission flown. Tables D-29 through D-64 list combat workload items in varying levels of importance categories based on the average ratings of pilots from each mission type. Evaluation of the pilots' ratings of combat workload items who flew Strategic Deterrence missions and "Other" missions in combat were neglected, because only two pilots flew Strategic Deterrence missions recently in combat, and because fifteen pilots specified that they flew various missions other than those provided in the survey questionnaire. Nevertheless, those combat workload items having "distractingly" important ratings in Strategic Deterrence and "other" missions are listed in Table 4-3b. As reported earlier in Chapter 3, it was intended to identify in-flight tasks that were believed to increase pilot workload "dangerously." As in the overall and aircraft groups' ratings, surprisingly, it was found

that no combat workload items were evaluated as "dangerously" important when the pertaining data were analyzed within each mission type. To save time and effort in analysis, examination of combat workload items found to be increase pilot workload "moderately," "some," "a little" or "not," and those rated as "not applicable" for the particular mission type are not listed in tables in this section. Instead, they are reported only in the text. The complete listing of items with means and standard deviations can be found in Appendix D.

Table 4-3a. Distractingly Important Combat Workload Items by Mission Type

Missions Flown	n	Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
Conventional Heavy Bombing	38	1. Threat Avoidance	1.8611	0.5929	1.0000	3.0000
		2. Crew Incapacitation	1.8611	1.2684	1.0000	6.0000
		3. Fatigue	2.0556	0.9545	1.0000	4.0000
		4. Night Low Level Navigation	2.2778	1.0853	1.0000	6.0000
		5. In-flight Emergency	2.3611	0.6825	1.0000	4.0000
		6. Aircraft Maneuvering	2.4444	1.0541	1.0000	6.0000
Theater Airlift	13	1. Threat Avoidance	2.0000	0.5774	1.0000	3.0000
		2. In-flight Emergency	2.2308	1.0919	1.0000	5.0000
		3. Crew Incapacitation	2.3077	1.2506	1.0000	5.0000
		4. Adverse Weather	2.3846	0.7679	1.0000	4.0000
Tactical Airlift	18	1. Threat Avoidance	2.2778	0.8264	1.0000	3.0000
		2. Fatigue	2.4444	0.9218	1.0000	4.0000
		3. In-flight Emergency	2.5556	1.1991	1.0000	5.0000
Air/Air Refueling	37	1. Crew Incapacitation	2.4324	1.5191	1.0000	6.0000
		2. In-flight Emergency	2.4865	0.9316	1.0000	5.0000
		3. Threat Avoidance	2.5676	1.0682	1.0000	5.0000

Table 4-3b. Distractingly Important Combat Workload Items by Mission Type

Missions Flown	n	Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
Air Superiority	8	1. Fatigue	2.0000	1.0690	1.0000	4.0000
		2. Threat Avoidance	2.2500	0.7071	1.0000	3.0000
		3. In-flight Emergency	2.3750	1.1877	1.0000	5.0000
		4. Adverse Weather	2.5000	1.3093	1.0000	4.0000
Close Air Support	26	1. Threat Avoidance	1.8462	0.8339	1.0000	3.0000
		2. In-flight Emergency	2.1154	0.7114	1.0000	4.0000
		3. Adverse Weather	2.3462	1.0561	1.0000	5.0000
		4. Aircraft Maneuvering	2.3846	1.0612	1.0000	4.0000
		5. In-flight No-notice Mission Changes	2.5385	0.8115	1.0000	4.0000
Air Interdiction	54	1. In-flight Emergency	2.2593	1.0494	1.0000	6.0000
		2. Threat Avoidance	2.4259	1.0569	1.0000	6.0000
Combat Air Patrol	10	In-flight Emergency	2.0000	0.9428	1.0000	4.0000
		Threat Avoidance	2.3000	1.0593	1.0000	4.0000
Strategic Deterrence	2	1. Threat Avoidance	2.0000	0.0000	2.0000	2.0000
		2. In-flight Emergency	2.0000	0.0000	2.0000	2.0000
		3. Aircraft Maneuvering	2.0000	0.0000	2.0000	2.0000
		4. Terrain Avoidance/ Terrain Following	2.5000	0.7071	2.0000	3.0000
		5. Adverse Weather	2.5000	0.7071	2.0000	3.0000
		6. In-flight No-notice Mission Changes	2.5000	0.7071	2.0000	3.0000
		7. Fatigue	2.5000	0.7071	2.0000	3.0000
Others	15	1. Threat Avoidance	2.1333	1.0601	1.0000	4.0000
		2. In-flight Emergency	2.2000	0.8619	1.0000	4.0000
		3. Aircraft Maneuvering	2.3333	0.8165	1.0000	4.0000
		4. Adverse Weather	2.3333	0.9759	1.0000	4.0000
		5. In-flight No-notice Mission Changes	2.4667	0.9155	1.0000	4.0000

Conventional Heavy Bombing Missions. Thirty-six pilots stated that they flew Conventional Heavy Bombing Missions in combat most recently. All pilots of this group flew the specified mission in B-52 aircraft. Combat workload items specified in each category of importance were exactly as those reported B-52 combat workload items. Based on the mean values of pilots ratings of those who flew Conventional Heavy Bombing missions, six combat workload items listed in Table 4-3a were identified as "distractingly" increasing pilot workload in combat. Among all combat workload items, Threat Avoidance was valued as the most important item. Fifteen combat workload items were evaluated as "moderately" important pilot workload. These are Adverse Weather, In-flight No-notice Mission Changes, Terrain Avoidance or Terrain Following, Equipment Degradation, Night Operations, Low Level Navigation, Maintaining Situational Awareness, Unfamiliar Terrain, Threat Detection, Crew Coordination, Target Acquisition, Command and Control, Managing Radio communication, Formation Responsibilities, and Responding to Ground or Airborne Controller Instructions (Table D-30). According to the average rating values of pilots of this mission type, nine "somewhat" important workload items are, in descending order of importance: Responding to Ground/Air Controllers Instructions, Management of TOT, Visual Orientation, Munitions Deployment, Type of Drop, Shifting Attention to Targets of Opportunity, Monitoring Flight Instruments, Refueling Operations, and Mission Planning (Table D-31). On the average, pilots of this mission type chose Mission Planning as the least important combat workload item. No combat workload item was found to be as "a

little" or "not" important, and there were no "not applicable" items. However, ten combat workload items were rated as "not applicable" at least one pilot.

Theater Airlift Missions. Thirteen pilots reported that they most recently flew Theater Airlift Missions in combat. All pilots of this group flew the particular mission in C-130 aircraft. Based on the mean values, four combat workload items listed in Table 4-3a were identified as "distractingly" increasing pilot workload in combat. Among all combat workload items, Threat Avoidance was valued as the most important item. Fourteen combat workload items that were evaluated as "moderately" important workload items. They were Fatigue, Aircraft Maneuvering, In-flight No-notice Mission Changes, Command and Control, Managing Radio Communication, Maintaining Situational Awareness, Equipment Degradation, Night Low Level Navigation, Threat Detection, Terrain Avoidance or Terrain Following, Low Level Navigation, Unfamiliar Terrain, Formation Responsibilities, and Visual Orientation (Table D-33). Pilots flying Theater Airlift missions in combat specified the following nine "somewhat" important combat workload items. They are, ranked in descending order of importance; Night Operations, Crew Coordination, Target Acquisition Mission Planning, Management of TOT, Monitoring Flight Instruments, Responding to Ground or Airborne Controller Instructions, and Type of Drop (Table D-34). Shifting Attention to Targets of Opportunity was found to be the only "a little" or "not" important item (Table D-35). Munitions Deployment and Air-to-Air Refueling Operations were identified as "not applicable" items (Table D-36).

Tactical Airlift Missions. Eighteen pilots reported that they most recently flew Tactical Airlift Missions in combat. Like pilots flying Theater Airlift missions, all pilots in this group also flew the mission in C-130 aircraft. According to average values of pilots' ratings of this mission type, three combat workload items listed in Table 4-3a were identified as "distractingly" increasing important. In this group also, Threat Avoidance was rated as the most important item. Table D-38 lists eighteen combat workload items that were evaluated as "moderately" important. They were Adverse Weather, Aircraft Maneuvering, Crew Incapacitation, Terrain Avoidance and Terrain Following, Maintaining Situational Awareness, Command and Control, Night Low Level Navigation, In-flight No-notice Mission Changes, Threat Detection, Managing Radio Communication, Mission Planning, Night Operations, Unfamiliar Terrain, Equipment Degradation, Low Level Navigation, Formation Responsibilities, Crew Coordination, and Visual Orientation. Among these eighteen items, pilots rated Adverse Weather and Aircraft Maneuvering evenly. Pilots who flew Tactical Airlift missions in combat specified five "somewhat" important combat workload items. They were Target Acquisition, Responding to Ground or Airborne Controllers Instructions, Management of TOT, Type of Drop, and Monitoring Flight Instruments (Table D-39). Shifting Attention to Targets of Opportunity was specified as "a little" or "not" important combat workload item (Table D-40). Like the pilots flying Theater Airlift mission, the pilots of this mission type rated Munitions Deployment and Air-to-Air Refueling Operations as "not applicable" items.

Air-to-Air Refueling Missions. Thirty-seven pilots who most recently flew Air-to-Air Refueling missions were KC-135 pilots. For this reason, combat workload items specified in each category of importance were exactly same as those of KC-135 pilots. Pilots of this mission type rated three combat workload items as "distractingly" increasing pilot workload in combat. They are listed in Table IV-3a. In this mission type, the combat workload item with highest level of importance was Crew Incapacitation. Table D-43 lists six combat workload items that were valued as "moderately" important. They were Fatigue, Adverse Weather, Equipment Degradation, In-flight No-notice Mission Changes, Formation Responsibilities, and Aircraft Maneuvering. Maintaining Situational Awareness, Command and Control, Managing Radio Communication, Threat Detection, Crew Coordination, Night Operations, Visual Operations, Responding to Ground or Airborne Controller Instructions, Refueling Operations, Mission Planning, Unfamiliar Terrain, and Monitoring Flight Instrument were identified as "somewhat" important combat workload items in combat (Table D-44). The following five combat workload items were considered as "a little" or "not" important workload items. These are Terrain Avoidance or Terrain Following, Night Low Level Navigation, and Shifting Attention to Targets of Opportunity (Table D-45). Target Acquisition, Type of Drop and Munitions Deployment were found to be "not applicable" to the particular mission type (Table D-46).

Air Superiority Missions. Six F-15 pilots and two F-16 pilots stated that they most recently flew Air Superiority missions in combat. Pilots of this mission type rated four combat workload items presented in Table IV-3b as "distractingly" important. In

this mission type, fatigue was rated as the most important combat workload item. Table D-48 presents seven combat workload items that were identified as "moderately" important in combat. They are Terrain Avoidance or Terrain Following, Crew Incapacitation, Night Operations, In-flight No-notice Mission Changes, Aircraft Maneuvering, Threat Detection, and Low Level Navigation. The following thirteen combat workload items were evaluated as "somewhat" important: Equipment Degradation, Shifting Attention to Targets of Opportunity, Maintaining Situational Awareness, Command and Control, Unfamiliar Terrain, Managing Radio Communications, Munitions Deployment, Formation Responsibilities, Mission Planning, Target Acquisition, Monitoring Flight Instruments, Night Low Level Navigation, and Visual Orientation (Table D-49). Management of TOT, Responding to Ground or Airborne Controller Instructions, Refueling Operations, and Type of Drop were four combat workload items considered as of "little" or "no" importance (Table D-50). Crew Coordination was found to be "not applicable" to the particular mission type (Table D-51).

Close Air Support. Twenty-five of 26 pilots who most recently flew Close Air Support missions in combat were AO/A-10 pilots, along with one F-16 pilot. Pilots flying this mission type rated four combat workload items presented in Table IV-3b as "distractingly" important in combat. Among these four, Threat Avoidance was the most important combat workload item. Thirteen combat workload items were identified as "moderately" important. They are Fatigue, Night Low Level Navigation, Night Operations, Equipment Degradation, Threat Detection, Target Acquisition, Terrain

Avoidance or Terrain Following, Crew Incapacitation, Unfamiliar Terrain, Maintaining Situational Awareness, Low Level Navigation, Shifting Attention to Targets of Opportunity, and Management of TOT (Table D-53). Ten combat workload items were found to be "somewhat" important workload items. They are Command and Control, Munitions Deployment, Managing Radio Communication, Responding to Ground or Airborne Controller Instructions, Visual Orientation, Formation Responsibilities, Mission Planning, Type of Drop, Monitoring Flight Instruments, and Refueling Operations (Table D-54). Crew Coordination was found to be "a little" or "not" important workload item (Table D-55). No combat workload item was rated as "not applicable" to this mission type.

Air Interdiction. Among the 54 pilots who most recently flew Air Interdiction missions in combat were six AO/A-10, two B-52, twenty-four F-15, and twenty-two F-16 pilots. Pilots' ratings of this mission type identified two combat workload items as "distractingly" important in combat. In-flight Emergency was rated as the most important one of all 29 combat workload items. Table 4-3b lists two "distractingly" important combat workload items. Twelve combat workload items with "moderately" important rating are listed in Table D-57. They were Aircraft Maneuvering, Adverse Weather, Equipment Degradation, In-flight No-notice Mission Changes, Crew Incapacitation, Fatigue, Night Low Level Navigation, Target Acquisition, Shifting Attention to Targets of Opportunity, Threat Detection, Maintaining Situational Awareness, and Night Operations. Terrain Avoidance or Terrain Following, Unfamiliar Terrain, Low Level Navigation, Munitions Deployment, Command and Control, Visual

Orientation, Managing Radio Communications, Management of TOT, Responding to Ground or Airborne Controllers Instructions, Formation Responsibilities, Mission Planning, Type of Drop, Monitoring Flight Instruments, and Refueling were the fifteen combat workload items with "somewhat" important workload rating (Table D-58). Crew Coordination was found to be of "little" or "no" importance (Table D-59). No combat workload item was valued as "not applicable" to this mission type.

Combat Air Patrol. Ten pilots reported that they most recently flew Combat Air Patrol (CAP) missions in combat. Among those ten pilots were one AO/A-10, one F-15, and eight F-16 pilots. Pilots flying this mission type rated two combat workload items as "distractingly" increasing pilot workload in combat. In-flight Emergency was rated as the most important one of all combat workload items. Table 4-3b lists two "distractingly" important combat workload items. Table D-61 lists nine combat workload items with "moderately" important rating. They are In-flight No-notice Mission Changes, Adverse Weather, Equipment Degradation, Fatigue, Threat Detection, Aircraft Maneuvering, Shifting Attention to Targets of Opportunity, Crew Incapacitation, and Unfamiliar Terrain. Pilots of this mission type determined the following fifteen combat workload items as having "somewhat" important rating. They are, listed in descending order of importance, Command and Control, Night Operations, Visual Orientation, Maintaining Situational Awareness, Target Acquisition, Night Low Level Navigation, Low Level Navigation, Mission Planning, Managing Radio Communications, Refueling Operations, Munitions Deployment, Type of Drop, Formation Responsibilities, Responding to Ground or Airborne Controllers Instructions,

and Terrain Avoidance and Terrain Following (Table D-62). Management of TOT and Monitoring Flight Instruments were rated as of "little" or "no" importance (Table D-63). Crew Coordination was evaluated as "not applicable" to this mission type (Table D-64).

A close examination of Tables 4-3a and 4-3b reveals that Threat Avoidance and In-flight Emergency were rated "distractingly" important within each mission group. Threat Avoidance was rated highest in four out of eight mission group evaluated, and it was present within the top three items of all mission types' listings. In-flight Emergency was present within the top five items of all mission groups, where it was rated as the most important item in two mission groups. Other common "distractingly" important combat workload items were Adverse Weather, Aircraft Maneuvering, Crew Incapacitation, and Fatigue, where Crew Incapacitation and Fatigue was present in top listings at least once. The combat workload items' listings of varying importance categories of Conventional Heavy Bombing missions and Air-to-Air Refueling missions were exactly same as those listings of B-52 and KC-135 aircraft, respectively because those missions were flown in the particular aircraft types. However, analysis produced different results for the combat workload items' listings of the missions flown in several different aircraft types than those listings of individual aircraft type. For instance, though Fatigue was not present in the listing of "distractingly" important combat workload items of F-15 or F-16 aircraft types, it was the top item in the listing of Air Superiority missions' "distractingly" important combat workload items. Although Tactical Airlift and Theater Airlift were flown on the same type of aircraft, C-130 Hercules, the listings of combat workload items varied between these two mission types. On both missions the survey was successful to

distinguish the same "not applicable" items for C-130 aircraft. These facts show that the survey was able to distinguish the workload items for different types of missions provided that the particular mission type are flown on different aircraft, or two missions are flown on the same type of aircraft.

Looking at the Tables 4-3a and 4-3b, it could be concluded that regardless of mission type flown, the worst scenario of pilot workload in combat exists when an in-flight emergency occurs while avoiding an enemy threat. The same degree of commonality is not observed in examining "moderately," "somewhat," and "a little" or "not" important combat workload item listings.

Analysis of Combat Workload Items Grouped by Experience Level

To compare the average ratings of "experienced" and "inexperienced" pilots, average combat workload items' ratings were evaluated separately based on the total flight hours, combat flight hours, and previous aircraft experiences excluding trainers. For B-52, C-130, and KC-135 pilots, "experienced" pilots were those with combat flying totaling more than 200 hours, and minimum total flying time of 2,000 hours, and at least one previous aircraft qualification. Similarly, for AO/A-10, F-15, and F-16 pilots "experienced" pilots had more than 100 combat flying hours, a minimum total flying time of 1,000 hours, and at least one previous aircraft qualification. Pilots not meeting these criteria were considered as "inexperienced." After segregating the data based on experience criteria, it was found that the data set contained 30 experienced and 189 inexperienced pilots. Tables 4-4a and 4-4b present the list of all combat workload item

responses linked to both "experienced" and "inexperienced" pilots, along with average rating and standard deviation values. Those "experienced" pilots' combat workload item ratings found to have significantly greater means than those of "inexperienced" pilots were marked with triple-asterisks.

In the first chapter, it was hypothesized that perception of combat workload of pilots with more flight experience would likely to be lower than those of inexperienced pilots. It should be remembered that, according to the five-point scale provided, the higher mean value of an item's rating implies the lower perception of workload by pilots on the particular combat workload item. To test this hypothesis, a two-tailed t-test was performed on every pair of combat workload items from "experienced" and "inexperienced" pilots' listings. The two-tailed t-test tested for a 95 percent confidence level. For the purpose of the test the null and the alternative hypotheses were modified as below.

> Null Hypothesis: The difference between the mean values of "experienced" and "inexperienced pilots' ratings = 0
>
> Alternative Hypothesis: The difference between the mean values of "experienced" and "inexperienced pilots' ratings > 0

To be conservative, the results of the test were determined assuming that sample pairs did not have equal variance. Based on the results of two-tailed t-test, only Managing Radio Communications were rated significantly less among "experienced" pilots in comparison with "inexperienced" pilots (Table 4-4b).

Table 4-4a. Comparison of Combat Workload Items

Combat Workload Item	Experienced Mean	Experienced Std.Dev.	Inexperienced Mean	Inexperienced Std.Dev.	Unequal Variance T-Value	Unequal Variance P-Value
1. Mission Planning	3.9000	1.3222	4.1368	1.1648	-0.9300	0.8197
2. Terrain Avoidance/ Terrain Following	3.3333	1.1547	3.4868	1.4052	-0.6500	0.7420
3. Maintaining Situational Awareness	3.2667	1.1725	3.3386	1.1353	-0.3100	0.6222
4. Adverse Weather	2.6000	1.0034	2.6667	1.0468	-0.3400	0.6307
5. Monitoring Flight Instruments	4.4000	0.8944	4.2857	0.9009	0.6500	0.2599
6. Equipment Degradation	2.8667	1.0080	2.9894	0.9839	-0.6200	0.7311
7. Low Level Navigation	3.9667	1.2452	3.7037	1.2953	1.0700	0.1459
8. Night Low Level Navigation	3.2667	1.5298	3.3704	1.6823	-0.3400	0.6322
9. Threat Avoidance	2.3667	1.1592	2.1905	0.8966	0.8000	0.2158
10. Formation Responsibilities	4.0667	0.9803	3.7407	0.9684	1.6900	0.0491
11. Management of TOT	4.1667	0.7466	4.1111	1.0383	0.3600	0.3615
12. In-flight No-notice Mission Changes	2.7333	0.8277	2.8677	0.9274	-0.8100	0.7893
13. Shifting Attention to Targets of Opportunity	3.4333	1.1043	4.2487	1.4464	-3.5900	0.9996
14. Munitions Deployment	4.1667	1.2617	4.5714	1.2426	-1.6400	0.9450
15. Threat Detection	3.4000	1.0700	3.3280	1.2197	0.3400	0.3695
16. Crew Incapacitation	2.2000	1.6897	2.6984	1.9458	-1.4700	0.9253
17. In-flight Emergency	2.3000	0.9879	2.3069	0.9289	-0.0400	0.5142
18. Visual Orientation	3.9310	1.3870	3.8883	1.1531	0.1600	0.4378
19. Command and Control (such as copying and decoding EAMS)	3.7333	1.3374	3.5904	1.1269	0.5500	0.2913
20. Fatigue	2.6000	1.3797	2.6349	1.0714	-0.1300	0.5523
21. Crew Coordination	4.7000	1.2077	4.3175	1.4085	1.5700	0.0615

Table 4-4b. Comparison of Combat Workload Items

	Experienced		Inexperienced		Unequal Variance	
Combat Workload Item	Mean	Std.Dev.	Mean	Std.Dev.	T-Value	P-Value
22. Aircraft Maneuvering (Dogfight or avoiding the threats)	2.9333	1.5071	2.7513	1.2576	0.6300	0.2671
23. Target Acquisition	3.6333	1.4016	3.8466	1.3925	-0.7700	0.7784
24. Type of Drop	4.3448	1.2034	4.5397	1.2181	-0.8100	0.7886
25. Night Operations	3.4333	1.1651	3.3333	1.0106	0.4400	0.3297
26. Unfamiliar Terrain	3.8667	1.0743	3.5661	1.0974	1.4200	0.0819
27. Managing Radio Communication ***	4.3333	0.8841	3.6667	0.9340	3.8100	0.0002
28. Refueling Operations	4.8000	0.6103	4.5661	0.9742	1.7700	0.0410
29. Responding to Ground/ Airborne Controller Instructions.	4.0665	1.0419	3.9781	0.9315	0.4400	0.3301

Confidence Interval Analysis of Combat Workload Items: Threat Avoidance

To compare the lower and the upper 95 percent confidence interval of Threat Avoidance, the item with the highest perception of workload, with other items, overall combat workload item ratings of all pilots were sorted in ascending order of their mean values. Tables 4-5a and 4-5b present the sorted data, in which Threat Avoidance has the lowest rating value among all combat workload items. The lower mean value of rating signified higher level of workload perception. Figure 4-11 illustrates the mean value of Threat Avoidance ratings by all pilots, which were significantly lower than mean values of all other combat workload ratings. As shown in the figure, the upper and lower 95 percent intervals of Threat Avoidance and those of In-flight Emergency coincide. In

other words, the mean value of Threat Avoidance ratings is significantly lower than mean values of all other combat workload ratings, except that of In-flight Emergency ratings.

Table 4-5a. Lower and Upper 95% Confidence Intervals of Combat Workload Items

Combat Workload Items	Lower 95% CI	Mean	Upper 95% CI	Significance
1. Threat Avoidance	2.0900	2.2146	2.3392	
2. In-flight Emergency	2.1814	2.3059	2.4304	
3. Crew Incapacitation	2.3748	2.6301	2.8854	***
4. Fatigue	2.4816	2.6301	2.7786	***
5. Adverse Weather	2.5192	2.6575	2.7959	***
6. Aircraft Maneuvering	2.6042	2.7763	2.9484	***
7. In-flight No-notice Mission Changes	2.7276	2.8493	2.9710	***
8. Equipment Degradation	2.8413	2.9726	3.1039	***
9. Maintaining Situational Awareness	3.1772	3.3288	3.4803	***
10. Threat Detection	3.1783	3.3379	3.4975	***
11. Night Operations	3.2098	3.3470	3.4843	***
12. Night Low Level Navigation	3.1352	3.3562	3.5772	***
13. Terrain Avoidance/ Terrain Following	3.2830	3.4658	3.6485	***
14. Unfamiliar Terrain	3.4612	3.6073	3.7534	***
15. Command and Control	3.4558	3.6101	3.7644	***
16. Low Level Navigation	3.5681	3.7397	3.9114	***
17. Managing Radio Communication	3.6310	3.7580	3.8850	***
18. Formation Responsibilities	3.6556	3.7854	3.9151	***
19. Target Acquisition	3.6319	3.8174	4.0028	***
20. Visual Orientation	3.7357	3.8940	4.0524	***
21. Responding to Ground/ Airborne Controller Instructions.	3.8793	4.0047	4.1301	***

Table 4-5b. Lower and Upper 95% Confidence Intervals of Combat Workload Items

Combat Workload Items		Lower 95% CI	Mean	Upper 95% CI	Significance
22.	Mission Planning	3.9468	4.1045	4.2623	***
23.	Management of TOT	3.9853	4.1187	4.2522	***
24.	Shifting Attention to Targets of Opportunity	3.9465	4.1370	4.3275	***
25.	Monitoring Flight Instruments	4.1817	4.3014	4.4211	***
26.	Crew Coordination	4.1852	4.3699	4.5545	***
27.	Type of Drop	4.3515	4.5138	4.6760	***
28.	Munitions Deployment	4.3495	4.5160	4.6825	***
29.	Refueling Operations	4.4736	4.5982	4.7227	***

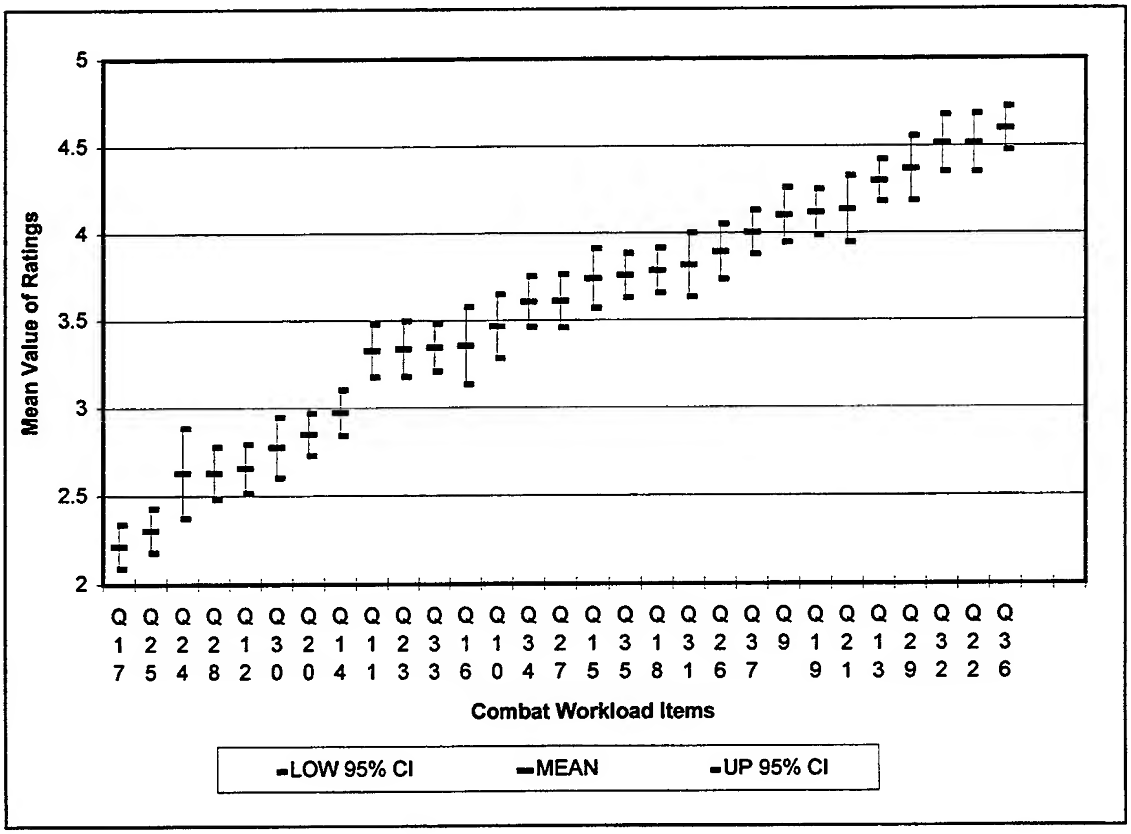

Figure 4-11. Range of Lower and Upper 95 % Confidence Interval

CWL (Combat Workload) Data Analysis

In this section, the overall CWL scores and those of different aircraft types are analyzed and the outcomes of the analysis are presented. In Chapter III, CWL was described as a variable which measures the overall perception of in-flight workload on a combat mission. Overall CWL score for each individual was calculated as a summation of their responses to significant combat workload items. CWL score of an individual could be as low as zero and as high as 135. A lower value of CWL score means that the pilot values his or her in-flight workload on a combat mission relatively higher than others. That is, the magnitude of the CWL score of a pilot is inversely related to the pilot's perception of in-flight workload on a combat mission. The frequency distributions of CWL are presented in separate diagrams. The results of stepwise regression to predict overall CWL score and that of the particular aircraft type are discussed. Finally, CWL scores are compared across aircraft types.

The methods to determine which of the combat workload items make up CWL were explained in Chapter III. The results of two methods, the Principal Component and Cronbach's alpha, are presented in Tables D-65a, D-65b and D-66 in Appendix D. Both of the SAS statistical software package outputs were reformatted for a better presentation. Based on the results of non-rotated factor analysis, the Principal Component, depicted on the SAS output in Table D-65, twenty seven out of twenty-nine combat workload items were eligible to create the CWL variable.

According to results of the Principal Component Analysis, Mission Planing and Monitoring Flight Instruments were excluded from the listing of combat workload items which make up the overall CWL scores. All combat workload items had a factor loading value of 0.3635 or higher. In addition to two combat workload items, the Principal Component Analysis pointed out all the remaining items, Questions 38 through 47, as survey items which were measuring factors other than that of CWL scores of pilots.

The results of Cronbach's alpha correlation analysis are presented in Table 4-6. The complete output of the correlation analysis can be found in Appendix D (Table D-66). A Cronbach's coefficient alpha value of 0.92 for both raw and standardized values, as indicated in Table 4-6, shows a very high internal consistency of CWL measure (SAS Institute, 1990: 214). This value suggests that most of the variance of CWL score is error-free, and accounted truly by the CWL score. In Table D-66 "correlation with the total values" represent the percentage of correlation of each item with the remaining combat workload items that make up the overall CWL score.

Table 4-6. Reliability Test of CWL--Correlation Analysis

Cronbach Coefficient Alpha	
for RAW variables	: 0.920502
for STANDARDIZED variables:	0.922903

Table 4-7 lists the CWL score statistics by aircraft type, as well as overall CWL score statistics. Statistical data were sorted by ascending order of the mean CWL score. Based on the average CWL score, it might be concluded that KC-135 pilots' perception

of in-flight workload on a combat mission were the highest of pilots flying other types of aircraft. F-16 pilots' perception of in-flight workload on a combat mission was the lowest of all. A casual look at the table also reveals that the mean CWL scores of KC-135, C-130, and A/AO-10 aircraft were below the mean of the overall CWL scores, while those of B-52, F-15, and F-16 aircraft were higher. Kurtosis and Skewness values show that CWL score distributions of all aircraft types are close to normal distribution, as well as the CWL score distribution of all pilots.

Figure 4-12 graphically illustrates the frequency distribution of CWL scores of all pilots. Similarly, Figures 4-13 through 4-18 depict the frequency distribution of CWL scores of each aircraft group. Normality of distributions in each case can also be seen from the graphs of the overall and the particular CWL score distributions.

Table 4-7. Statistics of Mean CWL Scores By Aircraft

Aircraft	Mean	Std. Dev.	Minimum	Median	Maximum	Skew	Kurtosis
KC-135	68.359	13.523	45	67.0	100	0.2683	-0.6489
C-130	74.719	15.361	33	77.5	101	-0.8049	0.3281
A/AO-10	78.588	12.432	46	78.0	104	-0.1328	0.3114
B-52	80.385	12.300	53	78.0	108	0.0322	-0.2460
F-15	83.773	17.741	17	87.5	118	-1.1118	2.9399
F-16	86.161	15.016	37	87.0	114	-0.7538	2.1882
Overall	78.635	15.601	17	79.0	118	-0.4160	0.7826

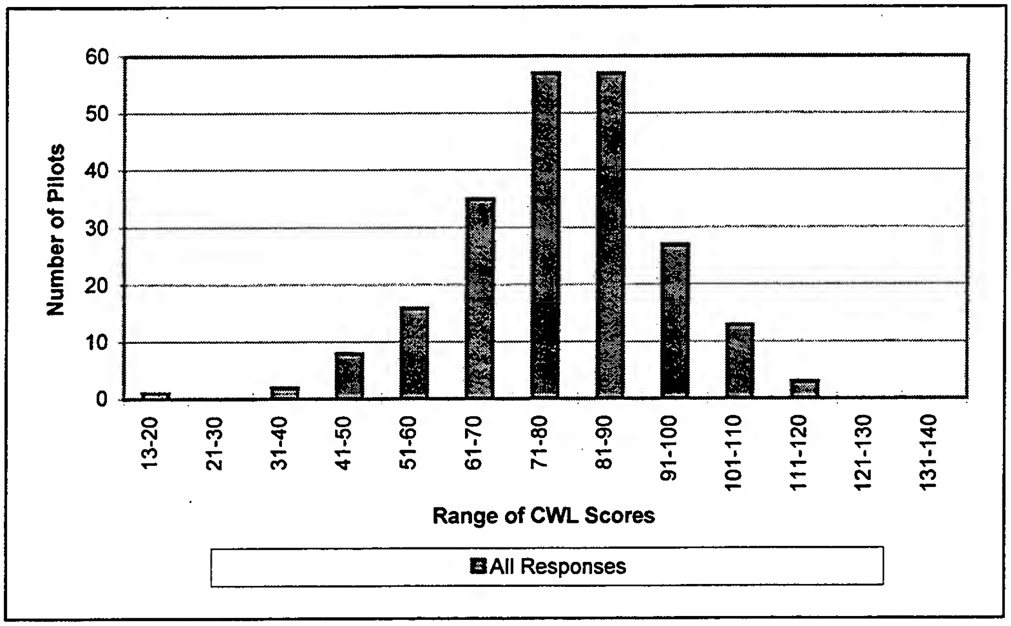

Figure 4-12. Distribution of Overall CWL Scores

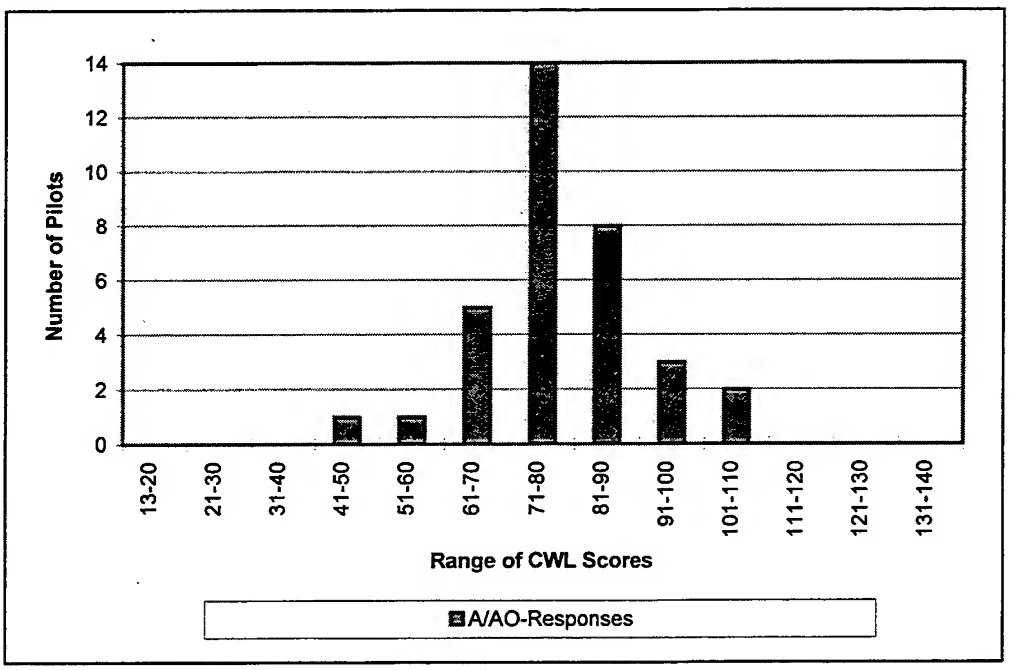

Figure 4-13. Distribution of A/AO-10 Pilots' CWL Scores

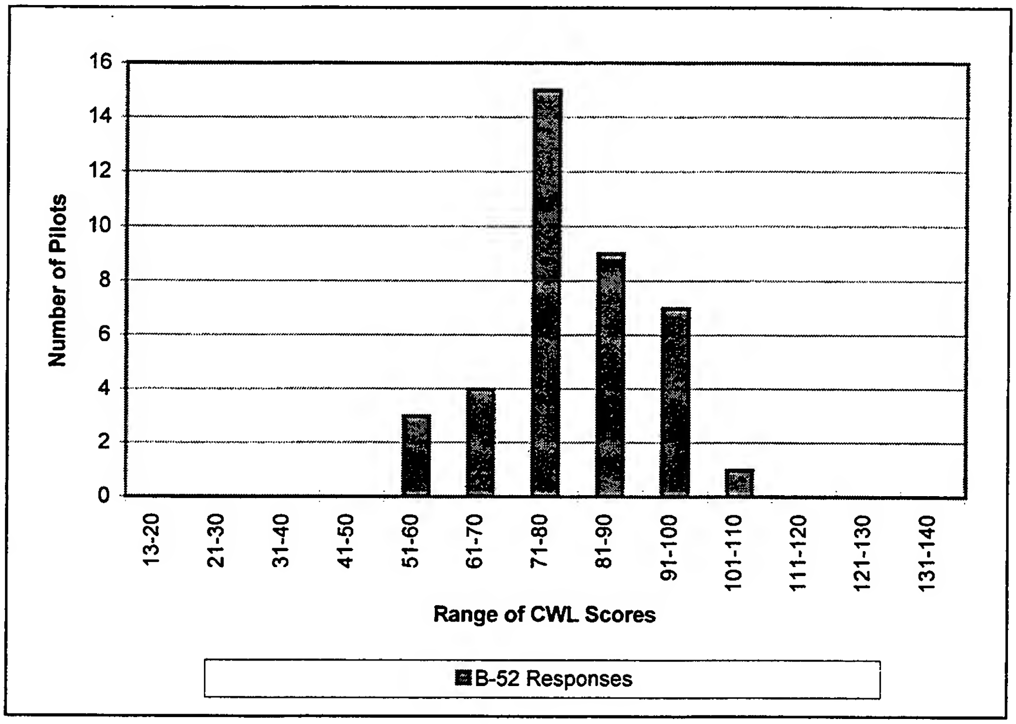

Figure 4-14. Distribution of B-52 Pilots' CWL Scores

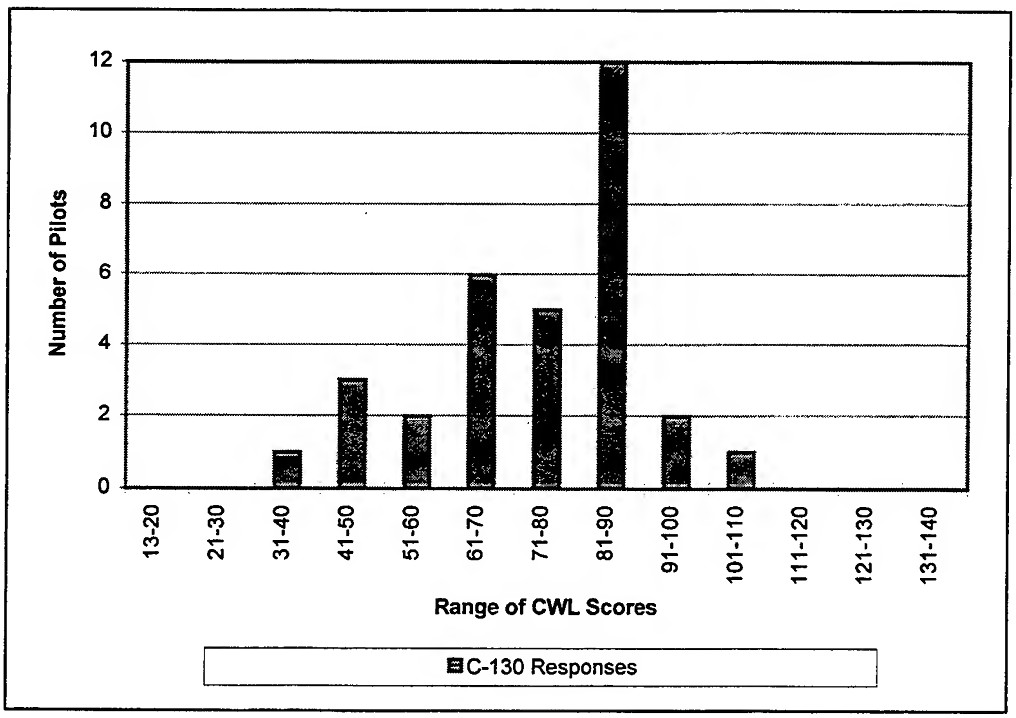

Figure 4-15. Distribution of C-130 Pilots' CWL Scores

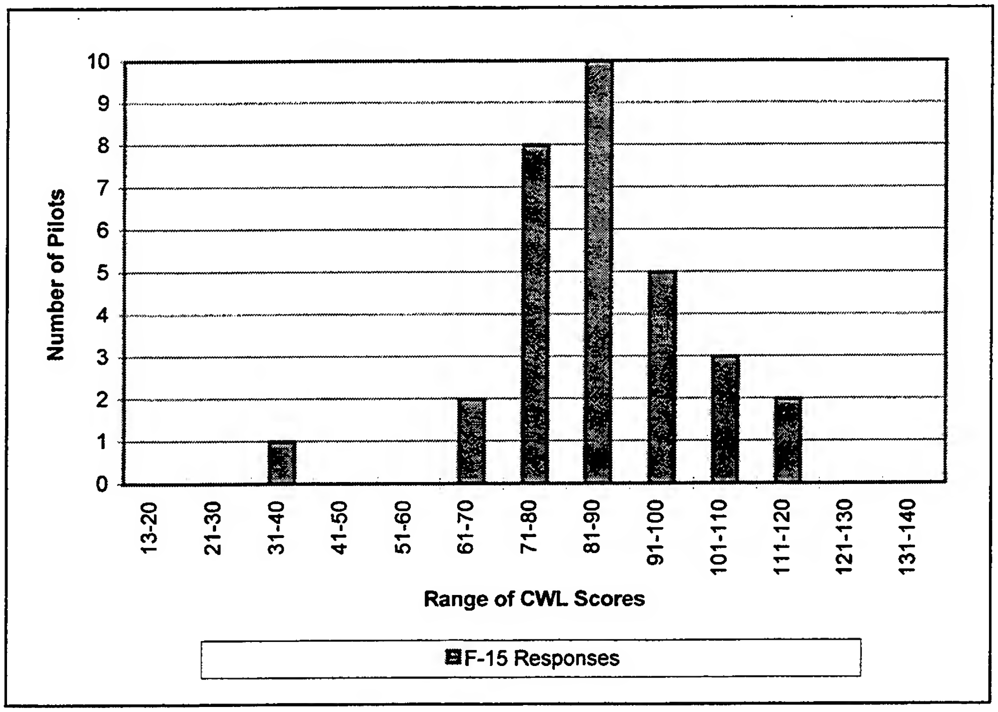

Figure 4-16. Distribution of F-15 Pilots' CWL Scores

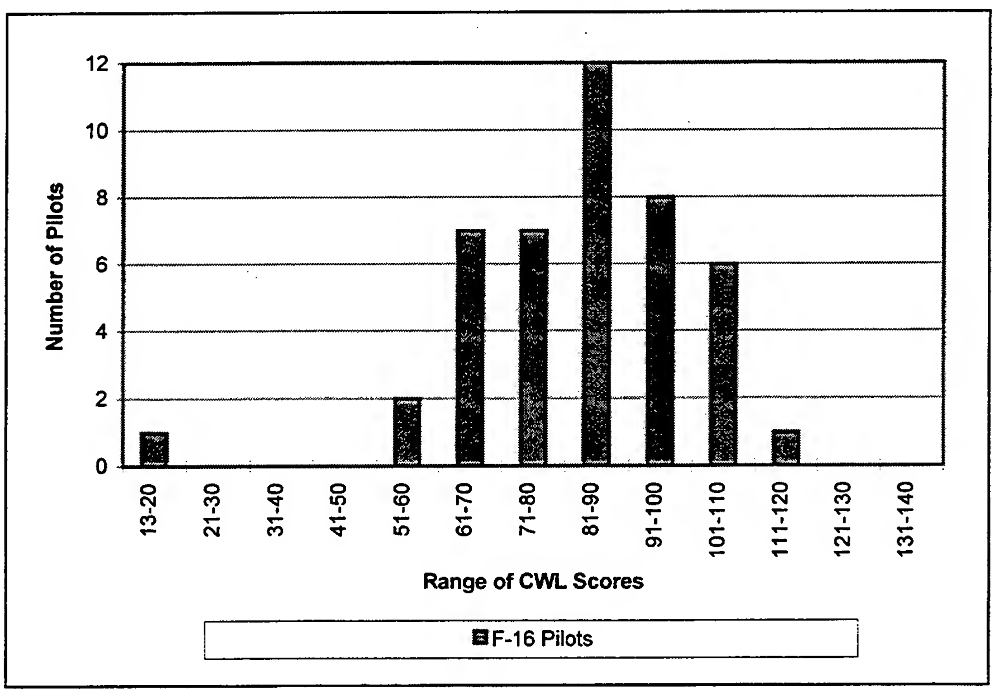

Figure 4-17. Distribution of F-16 Pilots' CWL Scores

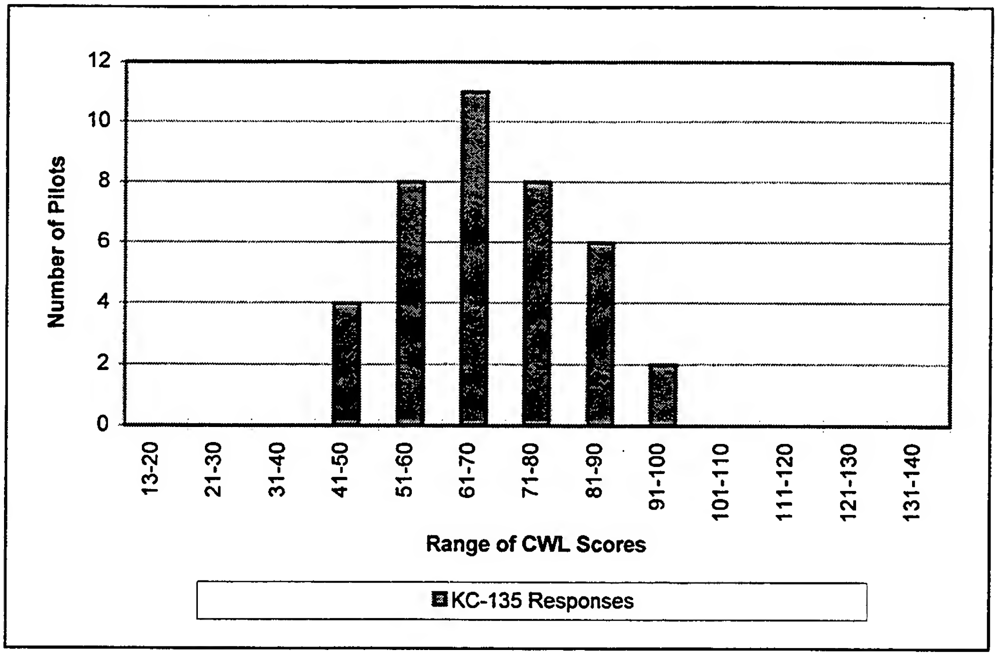

Figure 4-18. Distribution of KC-135 Pilots' CWL Scores

The stepwise regression routine resulted in the following independent variables and the associated coefficient values as shown in Table 4-8. The stepwise regression routine used the demographic data mentioned in Chapter III as independent variables to predict pilots' CWL score.

Table 4-8. Summary of Stepwise Regression Procedure for Dependent Variable -Overall CWL Score

Variable	Model R2	Estimate	F	Prob.>F
INTERCEPT		74.9004	537.63	0.0001
Q4 *	0.0425	-1.4652	5.49	0.0201
Q8 **	0.0682	1.6046	11.76	0.0007

* Q8: What mission did you fly in combat most recently?
** Q4: What is your current aircraft?

The result of the stepwise regression show that the model's R^2 value was as low as 0.0682, which means that only 6.82 percent of the variability of pilots' CWL scores can be explained by the two independent variables of the current aircraft flown, and most recent combat mission flown.

Next, a stepwise regression routine on SAS statistical software package was performed on the data grouped by aircraft type. Attempts to build a linear model to predict the CWL scores of pilots from each aircraft type failed. The summaries of stepwise regression routines for aircraft types are presented in Table 4-9. The highest R^2 of 0.1921 was achieved as result of stepwise regression procedure on C-130 data, which did not constitute a predictive model for CWL scores. Most models for aircraft resulted in one independent variable or two as predictors. Therefore, the use of these models, as well as the one in Table 4-8, to predict pilots' perception of in-flight workload on a combat mission is not supported.

Table 4-9. Summary of Stepwise Regression Procedure for Aircraft Types.

Aircraft	Variables	Model R2	F	Prob.>F
A/AO-10	Q1, Q8	0.0840	2.74	0.0815
B-52	Q1, Q6	0.1777	3.67	0.0360
C-130	Q6	0.1921	6.66	0.0154
F-15	Q5	0.1284	4.72	0.0374
F-16	Q6	0.1284	4.72	0.0374
KC-135	No Variable met the significance level of 0.015.			

Q1: What is your current rank?
Q5: Were you qualified in another aircraft previously?
Q6: How much combat time did you accumulate?
Q8: What mission did you fly in combat most recently?

One-way Analysis of Variance (ANOVA) procedures were performed on the independent variables which were included in stepwise regression. In analysis of variance, one is interested in testing whether a group of two or more means are equal (Elliot, 1995: 87). ANOVA procedures are conducted before Bonferroni procedures are performed. The one-way ANOVA procedure assures that a factor in a linear model is significant, that is, the means for the levels of that factor are equal (Elliot, 1995: 87). The results of the ANOVA procedures are reported in Table 4-10. All factors, independent variables, were found significant at the 95 percent significance level.

Table 4-10. Summary of One-Way ANOVA Procedure for CWL

Variable	df	F	Prob.>F
Q4	5	7.17	0.0010
Q6	6	2.27	0.0384
Q8	7	5.49	0.0010

Q4: What is your current aircraft?
Q6: How much combat time did you accumulate?
Q8: What mission did you fly in combat most recently?

Finally, the CWL scores were examined in terms of differences in mean CWL scores across the aircraft types. In Table 4-7 CWL score statistics were given including the mean CWL scores. The data were basically ordered in ascending order of the mean CWL score of each aircraft. The Bonferroni procedure provides multiple comparisons of

mean CWL scores. The Bonferroni procedure was performed on SAS statistical analysis software package at the 95 percent confidence level. Table D-67 in Appendix D presents the results of Bonferroni procedure. Table D-67 shows significant differences in mean comparison of the six aircraft types surveyed, and pairs of aircraft with a significant difference between them are indicated by triple-asterisks. The degree of pilots' perception of in-flight workload on a combat mission is showed in Table 4-11.

The results of the Bonferroni procedure reveal that there was no aircraft type in which pilots' perception of in-flight workload on a combat mission is significantly different than those of the remaining aircraft types. Mean CWL scores of pilots from each aircraft type were very close to each other. This can easily be noticed when Table 4-11 is examined closely. For instance, mean CWL scores of A/AO-10 pilots indicated that the in-flight workload perception of pilots varies between Level I, the lowest level of perception, and Level 4, the second higher level. Despite the significant indifference in means, KC-135 and C-130 pilots' perception of in-flight workload was rated at the highest level. In fact, C-130 pilots also appeared in lower three levels, Degrees II, III and IV. However, the table shows that KC-135 pilots' perceptions of in-flight workload were significantly different from those of pilots from four aircraft, F-16, F-15, B-52 and AO/A-10. This research examined only the mean scores of pilots from six aircraft types. A study including more aircraft types might reveal different ratings of pilots' perceptions regarding in-flight workload in combat.

Table 4-11. Summary of CWL Means by Aircraft-- Pilots' Perception of In-flight Workload on a Combat Mission

Degree of In-flight Workload	Aircraft Types
I (Lowest)	F-15 / F-16 / B-52 / A-10
II	F-16 / B-52 / A-10 / C-130
III	B-52 / A-10 / C-130
IV	A -10 / C-130
V (Highest)	C-130 / KC-135

Chapter Summary

Examination of the personal characteristics of pilots who participated in this research revealed that the sample group consisted of highly experienced pilots. Based on the criteria explained in Chapter III, one out of seven pilots had accumulated considerable amount of total USAF and combat flying time to be considered an "experienced" pilot. Most of the pilots had accumulated more than 1,000 hours of flying time, and at least some combat time. Almost all of the pilots had flown in combat. Nearly all of them had flown their current aircraft in combat.

The pilots' responses regarding combat workload items brought valuable insights to in-flight workload in combat and new facts regarding workload assessment. Pilots' perceptions of combat workload items revealed that no combat workload item was believed to increase pilot workload "dangerously" on a combat mission. However, they agreed that some combat workload items were likely to increase in-flight workload in a

distracting manner. Regardless of aircraft or missions flown, Threat Avoidance and In-flight Emergency were rated consistently higher among the combat workload items. Crew Incapacitation, Adverse Weather, Fatigue and Aircraft Maneuvering were other highly-perceived items. A worst case scenario for increased workload in a combat mission could be predicted as an in-flight emergency (or multiple emergency) occurring while avoiding a known enemy threat. The scenario could become more difficult if one or more of the other items mentioned above were added in. Nevertheless, differences in combat workload appeared in lower levels of importance when they were examined across different aircraft and mission types.

The analysis of CWL scores of pilots revealed that the mean CWL scores were distributed normally, both in general, and across different aircraft types. KC-135 pilots perceived in-flight workload on a combat mission significantly higher than pilots of other aircraft. However, the differences between mean CWL scores of pilots from six aircraft types were not significant; that is, mean CWL scores were very close to each other. Attempts to predict CWL scores based on the selected personal characteristics data via stepwise regression routine on SAS statistical analysis software package failed to produce significant findings.

In the next chapter, the findings of written material regarding in-flight workload assessment summarized in Chapter II, and the results of analysis of the data on pilots' perceptions of in-flight workload are blended in an effort to answer the questions introduced in Chapter I.

V. Conclusions and Recommendations

Chapter Overview and Introduction

In this chapter, two bodies of information, the review of the relevant literature in Chapter II, and the results of analysis of the survey data presented in Chapter IV, are integrated. By doing so, the main research question and the investigative questions, with their respective hypotheses, are answered.

Answers to each investigative questions are discussed in separate sections in this chapter. Depending on the nature of the questions, the discussion is detailed by aircraft or mission type flown. Answers to each question are derived from the results of data analysis, and they are supported by the findings of literature review and the related appendices when appropriate. Building on the answers to investigative questions, response to the main research question is provided.

Also in this chapter, recommendations for further researches are provided. These recommendations should provide insights to those individuals who want to take this research effort forward.

One appendix of this research project is devoted solely to the comments of pilots who provided their concerns and opinions. Appendix B, Survey Comments, contains representative opinions of pilots on in-flight workload assessment. Those pilots took extra time to include their comments after completing a prolonged survey.

<u>Investigative Question1: What pilot workload measurement systems have been developed that might pertain to a high-threat combat environment?</u>

An extensive review of literature found that there were four major group of workload assessment techniques: (1) Primary Task Performance Techniques, (2) Secondary Task Performance Techniques, (3) Physiological Measurement Techniques, and (4) Subjective Techniques. However, reviewing these techniques revealed that there is no suitable method of measuring workload in an aircraft while performing high threat combat missions. As Neville et al stated, unfortunately, no suitable methodology for measuring pilot performance in a wartime setting could be found (Neville et al, 1994: 346). The implementation requirements of most in-flight workload measures made it difficult to use them in the real world environment. Specifically, the use of these techniques in a combat environment with an existing enemy threat becomes almost impossible due to intrusiveness of the techniques and their impact on mission effectiveness. Most of the pilots who selected to write comments in response to Question 46a, which asked pilots to provide reasoning for not preferring to volunteer workload assessment experiments in combat, stated that combat environment is not the place for experimenting, or collecting data for empirical studies. A Major with 2501-3000 total flying hours and less than combat flying hours stated that "A combat sortie is inappropriate for testing. Where would the emphasis be—data collection or bombs on target? Would aircrews be required to perform nonstandard maneuvers, or fly in test modified aircraft? If the data collection was completely transparent, it might be acceptable." His comments point out that workload studies might be acceptable, but the

associated high risk, and cost of the study in terms of mission effectiveness should be considered.

Use of advanced simulators in assessing the workload in an high-threat environment could be considered; however, the effects of real threats are difficult to create realistically in a simulation world. The answers to a survey question regarding the effectiveness of simulators in creating realistic combat workload scenarios revealed some interesting information. Almost 2/3 of pilots (61.9 percent) disagreed that simulator missions flown in peace time adequately simulate the amount of workload that a pilot would experience in combat. Nearly 1/3 of pilots (28.6 percent) did not want to participate in experimental studies which measure in-flight workload in a simulated combat missions. Most pilots wanted to be excused from such experimental studies, because of lack of time, while others commented that simulator missions cannot realistically duplicate the combat environment.

In light of information gathered from the survey, and relevant literature, no pilot workload measurement system has been found as a proper means for assessing the in-flight workload in a high-threat combat environment.

Investigative Question 2: Is it possible to determine, from experienced pilots, what items would be most important in measuring workload in a high-threat environment?

To answer this question, 29 combat workload items were listed in the survey questionnaire, and pilots were asked to evaluate each item in terms of the degree to which they believed likely to increase the pilot workload in a combat environment.

Based on the average values of pilots' ratings, none of the combat workload items was found in itself to be "dangerously" important in regard to increasing pilot workload in a combat environment. From the list of 29 combat workload items, two combat workload items were valued as "distractingly" important. Threat Avoidance and In-flight Emergency (Table IV-2) were two combat workload items which pilots believed were likely to increase pilot workload "distractingly." Eleven combat workload items were rated as "moderately" important. They were, in descending order of importance Fatigue, Crew Incapacitation, Adverse Weather, Aircraft Maneuvering, In-flight No-notice Mission Changes, Equipment Degradation, Maintaining Situation Awareness, Threat Detection, Night Operations, Night Low Level Navigation, and Terrain Avoidance or Terrain Following (Table IV-3). The remaining sixteen combat workload were valued as "somewhat" important in terms of increasing pilot workload in combat.

By surveying a sample of 219 pilots, in which 98.2 percent had combat experience, it was possible to determine what items would be most important in measuring workload in a high-threat environment. Future researchers of the issue should concentrate on the worst scenario of combat workload, which appears to be the case of

having an emergency on the aircraft while avoiding an enemy threat. A more challenging scenario could occur when additional combat workload items are introduced into the picture. The designers of future aircraft should also keep this finding in mind, and they should concentrate their efforts on developing systems to improve pilot workload in such scenarios.

Investigative Question 3: Can any kind of consensus be reached to determine the relative priorities of workload items?

In an attempt to answer this particular question, the issue was further divided into four sub-investigative questions and respective hypothesis. First, answers to these four sub-questions were obtained by examining each hypothesis. Then, a final conclusion was reached on the answer of the third investigative question.

Investigative Question 3a: What do pilots of different aircraft type believe are the critical items that will increase their workload in a high threat combat environment?

It was hypothesized that pilots' perceptions of each aircraft type pertaining to the combat workload items would differ due to different characteristics of aircraft types. From a list of twenty-nine combat workload items, pilots from six aircraft types rated each workload item on a five-point scale ranging from "dangerously" to "a little" or "not" important. To eliminate the workload items which were not applicable to mission type or

aircraft flown, a "not applicable" selection was added to the list of choices. Surprisingly, as it was in overall ratings of pilots, no single combat workload item was consistently rated as "dangerously" important based on data segregated by aircraft type. In other words, pilots from six aircraft type think that no combat workload item "dangerously" increases in-flight pilot workload on a combat mission.

AO/A-10. Based on the average ratings of 34 AO/A-10 pilots surveyed, five combat workload items were found to be "distractingly" important (Table IV-2). They were Threat Avoidance, In-flight Emergency, Adverse Weather, Aircraft Maneuvering, and In-flight No-notice Mission Changes; among these five, Threat Avoidance was rated as the most important combat workload item. AO/A-10 pilots rated 14 combat workload items as "moderately" important items in workload assessment (Table D-5). Nine workload items were found to be "somewhat" important combat workload items (Table D-6). On the average, AO/A-10 pilots rated Crew coordination as of "little" or "no" importance, due to fact that they fly mostly single-seat models (Table-7). No combat workload item was evaluated as "not applicable" on the average. Night Operations and Night Low Level Navigation, as the top two "moderately" important items, might imply that AO/A-10 are not well-equipped for night flying. Furthermore, in valuing five items as "distractingly" important, which is almost twice as many as other two fighter type aircraft, pilots could be pointing out the technological differences in design of AO/A-10s, and F-15s and F-16s.

B-52 . Six combat workload items found to be "distractingly" important by 40 B-52 pilots (Table IV-2). These combat workload items were Crew Incapacitation, Threat

Avoidance, Fatigue, Night Low Level Navigation, In-flight Emergency, and Aircraft Maneuvering. Among all items, Crew Incapacitation was rated as the most important combat workload item. B-52 pilots' average ratings identified 14 combat workload items as "moderately" important items in combat workload assessment (Table D-9). According to the average rating values of B-52 pilots, the remaining nine combat workload items were determined as "somewhat" important where Mission Planning was specified as the least important combat workload item (Table D-10). No combat workload item was found to be of "little" or "no" importance, an there was no "not applicable" item. The design characteristics of B-52 play an important role in pilots determining the six "distractingly" important combat workload items. Since crew cooperation is vitally important, Crew Incapacitation was rated as the most important item in terms of increasing pilot workload. Fatigue is important, because most B-52 aircrew fly many hours on a sortie. B-52 pilots are also involved in many missions requiring them to fly Night Low Level Navigation, which is also present among six "distractingly" important items. In general, the selection of all 29 combat workload items in the survey was proper for this particular aircraft, because no workload item was valued as "not applicable" on the average. B-52 pilots selected the greatest number of combat workload items, as "distractingly" important among all aircraft, that is six items. This might imply that, in a high-threat environment, the mission requirement of the B-52 aircraft could create circumstances where more factors could cause task saturation.

C-130. Based on the evaluation of 32 C-130 pilots, five combat workload items were identified as "distractingly" important (Table IV-2). Among these five combat

workload items--which included Threat Avoidance, In-flight Emergency, Adverse Weather, Crew Incapacitation, and Fatigue--Threat Avoidance was evaluated as the most important combat workload item. Fifteen combat workload items evaluated as "moderately" important items in workload assessment according to C-130 pilots' average ratings (Table D-12). Pilots of this type specified six combat workload items as "somewhat" important (Table D-13). Shifting the Attention to Targets of Opportunity was valued as of "little" or "no" importance (Table D-14). Munitions Deployment and Refueling Operations were found to be "not applicable" to C-130 combat operations (Table D-13). Fatigue and Crew incapacitation were present in the top listing of combat workload items for C-130 aircraft, as they were for B-52 aircraft. As in AO/A-10s, Adverse Weather was rated in the top three important item. This might imply that both aircraft are not equipped with devices to fly in all-weather conditions. The survey was successful in detecting the two items, Munitions Deployment and Refueling Operations, as "not applicable" items, because most C-130 aircraft are not furnished with these capabilities.

F-15. Three workload items, In-flight Emergency, Crew Incapacitation, and Threat Avoidance, were measured as "distractingly" important (Table IV-2). Thirty F-15 pilots' average ratings determined nine combat workload items as "moderately" important items in combat workload assessment (Table D-17). According to the average rating values, the remaining 15 combat items were found to be "somewhat" important when assessing workload (Table D-18). F-15 pilots' choice of the least important combat workload item was Air Refueling Operations. No combat workload item was

found to be of "little" or "no" importance. Although almost two thirds of the combat workload items were rated as "not applicable" item by at least one pilot, none of them was valued as "not applicable" on the average. Crew Incapacitation was present among three "distractingly" important items. This could be due to the fact that sample of this surveys contained several pilots flying F-15E models which are two-seat versions of F-15 aircraft. Crew cooperation is important in mission success in F-15E aircraft.

F-16 . Only two combat workload items, In-flight Emergency and Threat Avoidance, were valued as "distractingly" important by 44 F-16 pilots (Table IV-2). Twelve combat workload items were found as "moderately" important items in combat workload assessment (Table D-20). Based on the average rating values, thirteen F-16 "somewhat" important combat workload items were determined. Air Refueling was valued as of "little" or "no" importance. Crew Coordination was rated as "not applicable" to F-16 aircraft due to fact that all F-16s, except training models, are single-seated fighter aircraft. On the other hand, Crew Incapacitation was rated as the last item on "the moderately" important item listing. Pilot might infer the case as themselves were incapacitated. F-16 pilots only two items as "distractingly" important; this might imply that the F-16 aircraft is equipped with advanced technologies which improves in-flight workload.

KC-135. Three combat workload items, which are found to be "distractingly" important by 39 KC-135 pilots, were Crew Incapacitation, In-flight Emergency, and Threat Avoidance (Table IV-2). KC-135 pilots valued six combat workload items as "moderately" important items in combat workload assessment (Table D-25). According

to the average rating values, twelve "somewhat" important combat workload items for KC-135s were determined (Table D-26). On the average, four combat workload items were valued as of "little" or "no" importance items. Target Acquisition, Type of Drop, and Munitions Deployment were found "not applicable" to KC-135 aircraft. As in all multi-seat aircraft, Crew Incapacitation was present among the top listings in KC-135 aircraft.

When survey data were analyzed, in general, it was found that the hypothesis was proved to be correct. When combat workload items of each aircraft in lower levels of importance were reviewed the hypothesis was most strongly supported. However, at the highest level of importance, when "distractingly" important combat workload items' listing was reviewed, the hypothesis appeared to fail. In the listings of combat workload items for each aircraft type, Threat Avoidance and In-flight Emergency were present, and they were rated as likely to increase pilot workload "distractingly" in combat. Threat Avoidance was present in all aircraft types within top three listings, and it was rated as the most important item in two aircraft types. In-flight Emergency was present in all aircraft listings within the top five combat workload items, and it was rated as the most in two aircraft types. Other common combat workload items found "distractingly" important across aircraft types were Crew Incapacitation, Fatigue, Adverse weather, and Aircraft Maneuvering. Among these combat workload items, Crew Incapacitation was rated as the most important item in two aircraft type. Therefore it is unfair to state that the hypothesis hold truth in the category of "distractingly" important combat workload items.

Despite the lack of commonality in lower levels of importance, it might be concluded that, regardless of aircraft type, the worst scenario of pilot workload in combat exists when an in-flight emergency occurs while avoiding a known enemy threat. It can be inferred that the selection of workload items was proper, because it represented common items of a combat mission for six aircraft types surveyed. AO/A-10, B-52 and C-130 pilots rated more items as "distractingly" important than pilots of F-15, F-16, and KC-135 aircraft. Technologies in the latter group of aircraft might be a factor in lower number of items in this category.

Finally, the answer to Investigative Question 3a could be concluded as the level of workload perceived by pilots changes depending the type of the aircraft flown; however, for those combat workload items with "distractingly" important rating, the level of workload perceived by pilots remains almost same by the type of the aircraft flown.

Investigative Question 3b: Does the level of workload perceived by pilots change depending on the type of the mission flown?

To investigate the answer the question above it was hypothesized that the ratings of combat workload items of pilots would change depending on the type of the mission flown. The entire data on twenty-nine combat workload items were segregated by mission type flown most recently. Strategic Deterrence was flown by only two of the pilots. Therefore, along with the data pertaining to the "other" category of mission flown, the Strategic Deterrence mission data were exempt from the analysis. Surprisingly, as

was true in overall ratings of pilots, and in ratings by aircraft type, no combat workload item was rated as "dangerously" important based on data segregated by mission type flown. The results of the analysis of combat workload items for each mission type are summarized below. Emphasis is given those workload items which were likely to increase pilot workload "distractingly."

Conventional Heavy Bombing Missions. Thirty-six of pilots surveyed flew Conventional Heavy Bombing Missions in combat most recently. All pilots of this group flew the specified mission in B-52 aircraft. Based on the mean values of pilots' ratings, six combat workload items were identified as "distractingly" important in combat (Table IV-3a). They were Threat avoidance, Crew incapacitation, Fatigue, Night Low Level Navigation, and In-flight Emergency. Among these six combat workload items, Threat Avoidance was valued as the most important item. Fifteen combat workload items were evaluated as "moderately" important (Table D-30). According to the average rating values of pilots of this mission type, nine combat workload items were identified as "somewhat" important (Table D-31). On the average, pilots of this mission type chose Mission Planning as the least important combat workload item. No combat workload item was found to be of "little" or "no" importance, and there were no "not applicable" items.

Theater Airlift Missions. Thirteen pilots most recently flew Theater Airlift Missions in combat. All pilots of this group flew the particular mission in C-130 aircraft. Based on the mean values, four combat workload items were identified as "distractingly" important in combat (Table IV-3a). These combat workload items were Threat

Avoidance, In-flight Emergency, Crew Incapacitation, and Adverse Weather. Fourteen combat workload items that were evaluated as "moderately" important (Table D-33). Pilots flying Theater Airlift missions in combat specified nine "somewhat" important combat workload items (Table D-34). No combat workload item was found to be of "little" or "no" importance. Munitions Deployment and Air-to-Air Refueling Operations were identified as "not applicable" items (Table D-30).

Tactical Airlift Missions. Eighteen of the pilots surveyed flew Tactical Airlift Missions in combat. Like pilots flew Theater Airlift missions, all pilots in this group also flew the particular mission in C-130 aircraft. Pilots' ratings of this mission type valued three combat workload items as "distractingly" important (Table IV-3a). Threat Avoidance, Fatigue and In-flight Emergency were the three combat workload items with "distractingly" important rating. Eighteen combat workload items that were evaluated as "moderately" important (Table D-38). Like the pilots flying Theater Airlift mission, the pilots of this mission type indicated Shifting Attention to Targets of Opportunity was specified as of "little" or "no" importance (Table D-40). Munitions Deployment and Air-to-Air Refueling Operations were identified as "not applicable" items (Table D-41).

Air-to-Air Refueling Missions. Thirty-seven pilots who most recently flew Air-to-Air Refueling missions were KC-135 pilots. Pilots of this mission type rated three combat workload items as "distractingly" important. They were Crew Incapacitation, In-flight Emergency, and Threat Avoidance. Six combat workload items that were valued as "moderately" important are listed in Table D-43. Pilots flying this mission type identified fourteen items as "somewhat" important combat workload items (Table D-44).

Five combat workload items were considered as of "little" or "no" importance workload items (Table D-45). Target Acquisition, Type of Drop and Munitions Deployment were found to be "not applicable" to the particular mission type (Table D-46).

Air Superiority Missions. Six F-15 and two F-16 pilots flew Air Superiority missions in combat. Pilots of this mission type rated four combat workload items as "distractingly" important. They were Fatigue, Threat Avoidance, In-flight Emergency, and Adverse Weather. Seven combat workload items were identified as "moderately" important (Table D-48). Thirteen of the remaining combat workload items were evaluated as "somewhat" important (Table D-49). Management of TOT, Responding to Ground or Airborne Controller Instructions, Refueling Operations, and Type of Drop were four combat workload items considered as of "little" or "no" importance (Table D-50). Crew Coordination was found to be "not applicable" to the particular mission type (Table D-51).

Close Air Support. Twenty-five of 26 pilots who most recently flew Close Air Support missions in combat were AO/A-10 pilots, along with one F-16 pilot. Pilots of this mission type rated four combat workload items presented as "distractingly" important. These combat workload items were Threat Avoidance, In-flight Emergency, Adverse Weather, and Aircraft Maneuvering. Thirteen combat workload items were identified as "moderately" important (Table D-53). Ten combat workload items were found to be "somewhat" important (Table D-54). One remaining combat workload item, Crew Coordination was valued as of "little" or "no" importance (Table D-55). No combat workload item was found to be "not applicable" to this mission type.

Air Interdiction. Among the 54 pilots who most recently flew Air Interdiction missions in combat were six AO/A-10, two B-52, twenty-four F-15, and twenty-two F-16 pilots. Pilots' ratings of this mission type identified two combat workload items as "distractingly" important, In-flight Emergency and Threat Avoidance (Table IV-3b). Twelve combat workload items were identified as "moderately" important (Table D-57). There were fifteen combat workload items with "somewhat" important workload ratings (Table D-58). Crew Coordination was found to be of "little" or "no" importance (Table D-59). No combat workload item was valued as "not applicable" to this mission type.

Combat Air Patrol. Ten pilots most recently flew Combat Air Patrol missions in combat. Among those were one AO/A-10, one F-15, and eight F-16 pilots. Pilots flying this mission type rated two combat workload items as "distractingly" important, In-flight Emergency and Threat Avoidance (Table IV-3b). Nine combat workload items were identified as "moderately" important (Table D-61). Pilots of this mission type identified fifteen combat workload items as "somewhat" important (Table D-62). Management of TOT and Monitoring Flight Instruments were rated as of "little" or "no" importance (Table D-63). Crew Coordination was evaluated as "not applicable" to this mission type (Table D-64).

It was found that the hypothesis holds true, especially when combat workload items of each aircraft are reviewed in lower levels of importance. However, when "distractingly" important combat workload items are investigated, the hypothesis is tentative. Threat Avoidance and In-flight Emergency were rated "distractingly" important within each mission group. Threat Avoidance was rated highest in four of eight

mission groups evaluated, and it was present within the top three listings of all mission types. In-flight Emergency was present within the top five listings of all mission groups, where it was rated as the most important item in two mission groups. Adverse Weather, Aircraft Maneuvering, Crew Incapacitation, and Fatigue were the other common "distractingly" important combat workload items. The main reason for such commonality stems from the fact that certain types of missions are flown by certain aircraft. For instance, KC-135 aircraft combat workload item categories are those of Air-to-Air Refueling missions; and, B-52 aircraft combat workload item categories and those of Conventional Heavy Bombing missions are the same. However, the combat workload items' listings of missions which are flown by several different aircraft types differ from those of individual aircraft type. For instance, although Fatigue is not present in the listing of "distractingly" important combat workload items of F-15 or F-16 aircraft, it is the top item in the listing of Air Superiority missions' "distractingly" important combat workload items. Although Tactical Airlift and Theater Airlift are flown on the same type of aircraft, the C-130 Hercules, the listings of combat workload items varies between these two mission types. On both missions the survey successfully distinguishes the same "not applicable" items. These facts show that the survey is able to distinguish among the workload items for different types of missions when the same missions were flown on different aircraft, or two missions are flown on the same type of aircraft. The combat workload item categories of other mission types are slightly different than those of aircraft in which particular missions were flown in combat.

Consequently, the answer to Investigative Question 3b could be concluded as the level of workload perceived by pilots changes depending the type of the mission flown; however, for those combat workload items with "distractingly" important rating, the level of workload perceived by pilots does not change by the type of the mission flown.

Investigative Question 3c: Does the level of workload perceived by pilots of each type vary by the experience level of the pilots?

It was hypothesized that pilots with more flight experience would be likely to specify higher ratings (lower perception of workload) for the combat workload items. To compare the average ratings of "experienced" and "inexperienced" pilots, average combat workload items' ratings were evaluated separately based on the criteria mentioned in Chapters III and IV. After segregation of the data, it was found that data set contained 30 experienced and 189 inexperienced pilots. To test the hypothesis, two-tailed t-tests were performed on each pair of combat workload items listed in Tables IV-4a and IV-4b. However, at the 95 percent confidence level, only Managing Radio Communication was significantly rated lower among "experienced" pilots in comparison to the "inexperienced" ones. Definitely, the hypothesis associating the lower rate of combat workload perception with increased level of experience is not supported. Thus, the answer to Investigative Question 3c is that the level of workload perceived by pilots of each type does not vary by the experience level of the pilots.

Investigative Question 3d: Is there a particular combat workload item that significantly possesses higher perception by all pilots?

It was hypothesized that the workload of "Threat avoidance" would be perceived as of greater significance than the other combat workload items by all pilots. Higher perception of workload was indicated by a lower value of mean rating according to Likert scale ratings used in the questionnaire (Appendix A). As stated in the previous chapter, Threat Avoidance was rated significantly lower than all other combat workload items except for In-flight Emergency at the 95 percent confidence level. The listing of 29 combat workload items in Tables IV-5a and IV-5b contains the lower and the upper values of mean scores at 95 percent significance level. Triple-asterisks indicate items whose mean values are significantly different than that of Threat Avoidance. Mean values of all items are significantly different than that of Threat Avoidance, except In-flight Emergency. As also shown graphically in Figure IV-11, lower and upper 95 percent interval ranges of Threat Avoidance intersect with those of In-flight Emergency. Therefore, this hypothesis is not supported although pilots' perception of workload of Threat Avoidance was highest of all combat workload items. Thus, the answer for Investigative Question 3d is that there is no particular workload item that posses significantly higher rating.

By reviewing the answers to all four sub-investigative questions, in general, it might be concluded that no consensus could be reached as to the relative priorities of workload items. However, when combat workload items are examined within the "distractingly" important category, Threat Avoidance and In-flight Emergency stand out

as the two of greatest importance in pilot workload assessment. The worst workload matrix would consist of Threat Avoidance and In-flight Emergency scenarios existing concurrently.

<u>Investigative Question 4: Could it be possible to enumerate combat workload perceptions of pilots overall, or those of pilots from different aircraft, depending upon their characteristic data?</u>

To answer this investigative question it was hypothesized that a model could be developed to predict combat workload perceptions of pilots in general, or those of pilots from particular aircraft by using pilot demographic data as independent variables.

The distribution diagrams describing Combat Workload (CWL) scores of the entire data set and those of different aircraft types were examined (Figure IV-12 through IV-18). CWL scores of individual aircraft were normally distributed, as well as that of the entire data. Attempts to develop a regression model that would predict CWL scores of pilots failed. In other words, the pilots' perception of in-flight workload on a combat mission could not be predicted by use of a regression model. Attempts to build similar models for each aircraft also failed.

However, the Bonferroni procedure was performed among the CWL scores of six aircraft types. The results showed that differences in means of the CWL scores for six aircraft were not significant; instead, they were very close in values. Despite the lack of significant difference among the means, KC-135 pilots' perception of in-flight workload

on a combat mission was significantly the higher than pilots from four other aircraft types, except C-130 pilots (Table IV-11). The similarities of mean values of CWL scores among pilots from six aircraft prevent us making broad statements about the conclusion of the Bonferroni procedure. It was surprising to find that a higher degree of perception of in-flight workload on combat missions was indicated by KC-135 pilots, because the number of KC-135 "distractingly" combat workload items was only three, fewer than that of four other aircraft types. Furthermore, KC-135 aircraft seldom fly missions in a high threat environment. They usually perform refueling missions over friendly territory. Because they are expensive and strategically important weapon systems, these aircraft are defended and escorted by advanced fighter aircraft resulting in lower risk of an enemy attack. Also, they usually refuel fighter packages at higher altitudes where the risk of enemy ground fire is nearly zero. Another surprising finding of the Bonferroni procedure was that F-16 pilots were in the lower segment of the workload perception scale. Perhaps this finding results from the fact that advanced technologies improve in-flight workload, although advanced technologies integrated into the F-16 cockpit demand higher performance from pilots who must accomplish their tasks by themselves. Like F-16 pilots, F-15 pilots appeared in the lower portions of the scale.

The research data overall do not support the hypothesis that pilots' perception of in-flight workload could be predicted by use of regression model.

In light of the answers to investigative questions, the answer to the main research question, "Based on the pilot experience, is it possible to assess pilot workload in a high threat combat environment?" could be concluded as follows: Although the findings of the

research data have brought many insights to workload assessment in combat or high-threat environment, it is highly optimistic to believe that in-flight workload in such an environment can assessed by the help exclusively of perceptions of experienced pilots.

Further Research

This research effort suggests future research in the following areas:

1. A follow-up of this study could be conducted among pilots of new weapon systems including B-1, C-17, C-141, F-111, and F-117 aircraft. A revised version of this survey could be administered to those pilots mentioned above to determine the impact of developed aircraft technologies on the pilots' perception of in-flight workload. The result could increase the validity of this research effort.

2. A similar study could investigate the degrees of in-flight workload perceived by pilots on different segments of combat missions. Combat workload items could be grouped under different mission segments such as take off and landing, en-route to the target area, within the target area, egress, and en-route home. Such a study might bring new insights to in-flight workload assessment in high-threat environment.

3. A follow-up study could be conducted among pilots who participate in training exercises such as FLAG and JRTC exercises. These exercises simulate the combat environment to a great extent, bringing on increased level of aircrew fatigue and in-flight workload.

Summary

The overall goal of this chapter was to answer the main research question introduced in Chapter I. The research question was: Based on the pilot experience, is it possible to assess pilot workload in a high threat combat environment? To determine the answer to main research question, four investigative questions were posed. First, answers to these investigative questions were found by use of respective hypotheses. Findings of Chapter IV and information gathered from previous chapters and related appendices were used to answer these investigative questions. In light of the answers to investigative questions, it was concluded that it would be highly optimistic to state that it was possible to assess in-flight workload in a combat or high-threat environment based on perceptions of experienced pilots.

Appendix A: The Cover Letter and The Survey Questionnaire

MEMORANDUM FOR ……………….
ATTENTION:

FROM: AFIT/LAC
2950 P Street
Wright-Patterson AFB, OH 45433-7765

SUBJECT: Survey Package of Pilots' Perception of Workload Assessment in Combat or High-Threat Environment-ACTION MEMORANDUM

1. Please take the time to complete the attached questionnaire and return it in the enclosed envelope by 15 September 1997.

2. The survey measures your perceptions of workload assessment in a high threat combat environment. The data we gather will become part of an AFIT research project and may influence future aircraft design and workload assessment techniques. Your individual responses will stay anonymous; and, combined with others, they will not be attributed to you personally.

3. This survey is unclassified, and all responses to the survey must be unclassified, so that the results can be releasable to the public domain.

4. Your participation is completely voluntary, but we would certainly appreciate your help. For further information, contact me at DSN 785-1213.

Dr. David K. Vaughan
Associate Dean, AFIT/LAC
Air Force Institute of Technology
Graduate School Acquisition and
Logistics Management
Email: dvaughan@afit.af.mil

INSTRUCTIONS

This survey is designed for U.S. Air Force officers with the aeronautical rating of PILOT, SENIOR PILOT, or COMMAND PILOT who have flown a single or multi-engine aircraft in combat or in a "combat environment" as described in the survey questionnaire. The survey should not be filled by any personnel other than those specified above.

This questionnaire consists of 53 items. All items except items 4, 5, 7, 37a, 44a, 45a, 46a, 47a and 48 are to be answered on the enclosed answer sheet, AFIT Form 11C. The remaining six questions are to be answered on the questionnaire booklet. If you select the "other" choice as an answer for applicable questions, please specify your answer in the space provided (x..................(specify)) in the questionnaire booklet after you have marked the "other" choice on the answer sheet.

The answer sheet and the questionnaire booklet should be mailed in the pre-addressed envelope provided NLT 15 September 1997.

Please use a No. 2 lead pencil, and remember the following points:

1. Make heavy black marks
2. Erase neatly when needed.
3. Make no stray markings.
4. Do not staple, fold or tear the response sheet.

We remind you **NOT** to fill in your name on any of the papers so that your answer will remain anonymous.

USAF Survey Control Number (SCN): 97-52
Expiration Date: 31 October 1997

Survey Questionnaire

USAF PILOT SURVEY OF FLIGHT WORKLOAD IN A COMBAT

ENVIRONMENT

For the purpose of the present study the "combat environment" is defined as any flight environment where the USAF aircraft are likely to be exposed to any type of non-friendly ground or enemy defense systems capable of firing. In parallel to the definition above, "combat flights" are defined as those flights conducted in any "combat environment." Peacetime training flights which are conducted to simulate a wartime environment like Red Flag are also considered as "combat flights."

PERSONAL CHRACTERISTICS

1. What is your current rank?

    1. Second Lieutenant
    2. First Lieutenant
    3. Captain
    4. Major
    5. Lieutenant Colonel
    6. Colonel

2. What is your gender?

    1. Female
    2. Male

3. How many hours of flight experience do you have, excluding flight training ?

    1. less than 500 hrs.
    2. 501-1000 hrs
    3. 1001-1500 hrs
    4. 1501-2000 hrs
    5. 2001-2500 hrs
    6. 2501-3000 hrs
    7. over 3000 hrs x............ hrs (specify)

4. What is the current aircraft you are flying or the most recent aircraft you flew? x......................(specify)

5. What other aircraft have you flown? (Please list in reverse chronological order—Most recent first, and so on.)

   x..(specify)

   x..(specify)

   x..(specify)

6. How many hours of flight experience do you have in combat (officially logged combat hours)?

   1. none
   2. less than 100 hours
   3. 101-200 hours
   4. 201-300 hours
   5. 301-400 hours
   6. 401-500 hours
   7. more than 500 hour

   x..(specify)

7. What type(s) of aircraft did you fly in combat? (Please see the definition of combat above, and list them in reverse chronological order, if more than one.)

   x..(specify)

   x..(specify)

8. What primary mission did you fly in combat? (Please specify the most recent one if you participated in combat more than once.)

   1. Strategic Deterrence
   2. Conventional Heavy Bombing Operations
   3. Theater Airlift
   4. Tactical Airlift
   5. Air-to-Air Refueling
   6. Air Superiority
   7. Close Air Support
   8. Air Interdiction
   9. Combat Air Patrol
   10. Other x..(specify).

WORKLOAD FACTORS

For the rest of the questions presented in this questionnaire, please answer them according to the aircraft you specified for Question 4.

For questions 9-37, please evaluate each of the following factors in terms of the degree to which you believe each is likely to increase the pilot workload in a combat environment. Please assign a value between 1 to 6 according to the Likert scale provided. In this scale:

"Dangerous increase" means any increment in workload that might cause extreme delays in the task currently being performed or unsafe situations or mission failure.

"Distracting increase" means any increment in workload that might cause excessive delays in the task currently performed, or recoverable unsafe situation or decrease in mission performance.

"Moderate increase" means any increment in workload that might cause moderate delays in the task currently being performed.

"Some increase' means any increment in workload that might cause some delays in the task currently being performed.

"Little or No increase" means any increment in workload that might cause little or no delay in the task currently being performed.

1. Dangerous Increase 2. Distracting Increase 3. Moderate Increase 4. Some Increase 5. Little or No Increase 6. Not Applicable

9. Mission Planning	1	2	3	4	5	6
10. Terrain Avoidance/Following	1	2	3	4	5	6
11. Maintaining Situational Awareness	1	2	3	4	5	6
12. Adverse Weather	1	2	3	4	5	6
13. Monitoring Flight Instruments	1	2	3	4	5	6
14. Equipment Degradation	1	2	3	4	5	6
15. Low Level Navigation	1	2	3	4	5	6

For questions 16-30, please evaluate each of the following factors in terms of the degree to which you believe each is likely to increase the pilot workload in a combat environment?

1. Dangerous Increase	2. Distracting Increase	3. Moderate Increase	4. Some Increase	5. Little or No Increase	6. Not Applicable

16. Night Low Level Navigation	1	2	3	4	5	6
17. Threat Avoidance	1	2	3	4	5	6
18. Formation Responsibilities	1	2	3	4	5	6
19. Management of TOT	1	2	3	4	5	6
20. In-flight, No-Notice Mission Changes	1	2	3	4	5	6
21. Shifting Attention to Targets of Opportunities	1	2	3	4	5	6
22. Munitions Deployment	1	2	3	4	5	6
23. Threat Detection	1	2	3	4	5	6
24. Crew Incapacitation	1	2	3	4	5	6
25. In-flight Emergency	1	2	3	4	5	6
26. Visual Orientation	1	2	3	4	5	6
27. Command & Control (such as copying&decoding EAMS)	1	2	3	4	5	6
28. Fatigue	1	2	3	4	5	6
29. Crew Coordination	1	2	3	4	5	6
30. Aircraft Maneuvering (Dogfight or avoiding the threats)	1	2	3	4	5	6

For questions 31-37, please evaluate each of the following factors in terms of the degree to which you believe each is likely to increase the pilot workload in a combat environment?

1. Dangerous Increase	2. Distracting Increase	3. Moderate Increase	4. Some Increase	5. Little or No Increase	6. Not Applicable

31. Target Acquisition	1	2	3	4	5	6
32. Type of Drop	1	2	3	4	5	6
33. Night Operations	1	2	3	4	5	6
34. Unfamiliar Terrain	1	2	3	4	5	6
35. Managing Radio Communication	1	2	3	4	5	6
36. Refueling Operations	1	2	3	4	5	6
37. Responding to Ground/Airborne Controller instructions.	1	2	3	4	5	6

37a. Do you have any thing to add to the list above? (Please write your answer below, or skip the question if your answer is no.)

For Questions 38-44, please evaluate each statement in terms of the degree that you agree with each statement by using the following scale.

1. Strongly agree	2. Agree	3. Neutral	4. Disagree	5. Strongly Disagree

38. Additional aircrew could reduce the workload in a combat environment (Assuming that your aircraft could be designed in such a way to accommodate the additional aircrew such as Weapon Systems Officer (WSO), Electronic Warfare Officer (EWO), Navigator, or Radar Intercept Officer (RIO).

1 2 3 4 5

For Questions 39-44, please evaluate each statement in terms of the degree that you agree with each statement by using the following scale.

1. Strongly agree	2. Agree	3. Neutral	4. Disagree	5. Strongly Disagree

39. Modifying the cockpit resources of your aircraft could help to eliminate the excess workload in the cockpit of the aircraft you flew in combat.

    1 2 3 4 5

40. Technological innovations in future aircraft designs will help reduce the workload.

    1 2 3 4 5

41. Updating the current operational regulations and procedures could help eliminate excess workload in the cockpit of the aircraft you fly or the most recent aircraft you flew.

    1 2 3 4 5

42. The workload of combat flight operations is heavier than that of peace time operations.

    1 2 3 4 5

43. Simulator missions flown in peace time adequately simulate the amount of workload that a pilot will experience in combat.

    1 2 3 4 5

44. In combat, the superiority of the U.S. and allies' air power over that of enemies would have an positive impact in reducing the amount of workload experienced during in-flight operations.

    1 2 3 4 5

44a. During peace time operations (or training missions), what scenario or procedure did you think would be most difficult to handle in combat (such as being detected by the enemy defense, or having a emergency in the target area)? (Please write your answer below.)

45. Did you find it (Question 44a scenario) difficult to handle in the combat environment?

1. Yes, even harder than I had expected.
2. No, it was about the same.
3. It was less.
4. Not applicable

45a. If your answer to the Question 45 is "It was less," was there any procedure that you found more difficult to handle than you expected? (Please write your answer below, or skip if not applicable.)

46. Would you volunteer to participate in experimental studies which measure workload using data collected in flight in a combat environment?

1. Yes
2. No.

46a. If your answer to Question 46 is "No," please write your reason.

47. Would you volunteer to participate in experimental studies mentioned above in a simulated combat mission?

1. Yes
2. No.

47a. If your answer to Question 47 is "No," please write your reason.

48. Please at this moment feel free to make any comment about the issues discussed in the survey itself. You may use the available space on this page or attach extra paper if you need.

Appendix B: Survey Comments

Introduction

The final question, Question 48, on the survey questionnaire invited pilots to make any comments regarding the issues discussed in the survey. There was no attempt made to guide respondents to provide a particular information or to discuss a specific issue. The comments were made to clarify or to detail the opinions of pilots who elected to express their concerns about pilot workload and combat. Comments on Questions 46a, and 47a, were included in the appendix, if respondents elected to answer the questions. These questions asked pilots to provide reasoning for not preferring to volunteer workload assessment experiments in combat missions and simulators, respectively. The comments on the structure and contents of the survey were exempted from the appendix. Overall, the comments of pilots with combat experience should provide valuable insights into combat workload assessment. The comments are also useful for making qualitative judgments on the statistical data. Below, listed are the pilots' comments from six aircraft surveyed concerning Questions 46a, 47a, and 48.

AO/A-10

Ten pilots elected to include their comments.

Question 48: Workload in combat and the ability to deal with it is a direct result of training! We need to train to go to combat! Simulators do not do it. We need to fly the missions on tactical ranges, employ weapons, and learn from our mistakes. Bottom line: experience is the answer that you are looking for.

2. Major, 2001-2500 total flying hours, less than 100 combat flying hours:

   Question 48: We, the Air Force members, need to quit focusing our technological energies or money on fighting the last war (Desert Storm); and we should think towards future conflicts which will be low intensity and permissive threat environments. All the cockpit magic in the world will not be helpful if the pilot and/or the ground commander does not know where the friendlies are. The EPLARs-SADL system is a good start. Identifying targets and friendlies in an urban, jungle or mountain environment with no clear lines of demarcation and merged forces is where your focus should be.

3. Captain, 2001-2500 total flying hours, 301-400 combat flying hours:

   Question 48: A-10 needs a reliable, fully navigation-modified cockpit and GPS.

4. Captain, 2501-3000 total flying hours, 210-300 combat flying hours:

   Question 46a: Combat is not the time for studies and experimentation; however, most of what is being logged as "combat flights" these days (Southern/Northern Watch, Bosnia) is not really combat anyway. So, it might be appropriate.

   Question 48: Any modifications to aircraft that make the cockpit more "pilot friendly," (i.e. better ergonomics, switch positions, etc.) will be beneficial for combat operations. Also, the more automated the weapon delivery system is, the easier it will be for the pilots to concentrate on target acquisition and staying alive.

5. Major, 2001-2500 total flying hours, less than 100 combat flying hours:

   Question 48: Desert Storm was not the best test for a high threat war. Some combat pilots flew definite high threat missions; but, many were low threat tactics. Medium-altitude tactics are very different in high-threat or medium-threat areas. It should be kept in mind while assessing workload.

6. Colonel, 2501-3000 total flying hours, less than 100 combat flying hours:

   Question 46a: I have participated in workload assessment studies before. The results are pre-determined; and, the goal of the testing is to achieve those results. In any case, the results are meaningless unless they result in something removed from the cockpit before anything may be added.

7. Major, 2501-3000 total flying hours, less than 100 combat flying hours:

   Question 46a: I would have enough to worry about in combat without adding academic studies to my workload. I do not want anything unfamiliar to me that I can control in the cockpit in a combat environment.

   Question 48: As new systems are contemplated to make air and space power more, we must always remember that combat is very complex; and, so are the air operations. The fact that we may have "made it look easy" should not fool us into thinking it is. I get very nervous when folks talking about re-targeting a mission after the crews have thoroughly planned to do something else. We cannot think of air power in the same way as we think of artillery—just plug in new coordinates, move the barrel, and pull the lanyard. Air operations are not that simple. Routes have to be planned and de-conflicted based on a number of factors. Some of these are threats, weather, tankers, EW support, ground and naval operations, fuel required, avenues of approach, target type, target acquisition, perhaps moon illumination, elevation and etc. These are all factored into planning each mission and thoroughly briefed. To expect crews to able to just input new coordinates, and "using it," especially for interdiction, counter-air and strategic attack operations is to unnecessarily risk the lives of the crew and the aircraft. Expect increased losses, and decreased mission effectiveness. Certainly, CAS and some air superiority missions lend themselves more to flexibility. However, in most cases even CAS missions are re-targeted within the a general area (not always though).

Crews still need time to plan, come up with backups, and study the target(s) against which they are being asked to risk their lives whenever possible. The ability to rapidly re-target is appealing and necessary; but, those making decisions in the air operations centers must always weigh the added risk you expose your force to when you send it in with less than thorough preparation.
Emphasis needs to be on getting needed intelligence to the aircrew (preferably for mission planning). Also, the emphasis should be placed on systems like data modems to automatically load targets, IP, and checkpoints, into navigation systems in flight. Target acquisition aids in greater standoff and resolution are needed. The need for identifying friends or enemies positively, the need for better and automatic radar and IR threat countermeasure systems, and the need for improved situation displays that incorporate near-real time data like Joint STARS, AWACS, should also be emphasized.

8. Captain, 1001-1500 total flying hours, less than 100 combat flying hours:

Question 48: One item which affected me a lot by loading on more stress and fatigue was the twice nightly attacks which interrupted my sleep patterns. We would be awakened by sirens at approximately 2200 and 0200 hours every night. Each night we had to put on full chemical gear and jump into bunkers for about an hour at a time. Then, we would still get up at dawn, and fly two to three sorties of combat missions.

9. Captain, 2001-2500 total flying hours, 201-300 combat flying hours:

Question 48: A true combat environment is tough to simulate. We train hard to a combat environment, but until the shooting starts, and the possibility of death exists, you can never gather accurate information. Emotions run high in combat and some people perform better in that environment then others. I have trained with some of the best, but in a combat environment personalities change.

10. Captain, 1501-2000 total flying hours, less than 100 combat flying hours:

Question 48: One of the biggest problems is communications with multiple ground agencies. So many users on the same frequency tend to jam the communication on the frequency. Also, the layout of the radios in the A-10 causes excessive "hands-down" time when switching frequencies.

B-52

Ten B-52 pilots elected to write comments.

1. Major, 2501-3000 total flying hours, 201-300 combat flying hours:

   Question 48: I found combat flying much easier than training. Reason: many of peacetime micromanagement rules went away, and real goal of fly, fight, and win came to the surface.

2. Major, 2501-3000 total flying hours, 201-300 combat flying hours:

   Question 46a: Why would I want to make combat more challenging by trying to study it—added tasks with dubious valve? I do not think that I would prefer that.

   Question 47a: Because, you cannot simulate the stress of life and limits without actually risking them—the study will produce fatally flawed outcomes.

3. Major, 3100 total flying hours, 101-200 combat flying hours:

   Question 48: The B-52 combat mission tasks are far easier at high altitude than they are at low altitude such as Air Superiority, Terrain Avoidance, and Weapon Delivery, etc. My answer related to the worst case scenario, my two low level combat sorties. That may be a moot point, especially if the buff will never go low again.

4. Captain, 1001-1500 total flying hours, no combat flying hours:

   Question 48: Communication, internal and external, is a major player in increasing workload. We have 3 UHF/VHF radios, IHF, secure voice, have-quick, SATCOM, and more. It is tough to monitor too many sources while attempting to attack a target.

5. Major, 3100 total flying hours, 101-200 combat flying hours:

   Question 47a: Simulators cannot match the required stress loads on pilots.

6. Major, over 3000 total flying hours, 101-200 combat flying hours:

   Question 48: Simulators are still very limited in raising pucker factor. There is no threat of death, aircraft response is not quite the same, and "fog of war" difficult to evaluate.

7. Captain, 2001-2500 total flying hours, 101-200 combat flying hours:

   Question 48: I believe this study is well worth the effort. Given the correct state of personnel management, I do not believe there are still a significant number of active duty flyers with combat experience. That loss of experience base could be very costly to regain.

8. Colonel, 2001-2500 total flying hours, less than 100 combat flying hours:

   Question 47a: You cannot truly re-create a combat mission. Training rules cannot, and should not allow it.

   Question 48: Despite the success of Desert Storm, we all know that a war is not won in the skies, but on the ground. As glamorous as air combat may seem to be, we are an extension of ground combat. We need to keep that in mind.

9. Captain, 2501-3000 total flying hours, 101-200 combat flying hours:

   Question 48: It takes more than new airframes to solve pilot concerns and combat workloads. Many (systems) technologies which work, are available, and could be pun on older aircraft to reduce workload and greatly increase threat penetration. Developing new aircraft and capabilities is a given, but upgrading current systems must be given top priority. If an aircraft cannot pull 10 G's or needs only a small amount of funding to upgrade its current ECM system, DO IT! You can keep my pilot bonus if you have to to do it!! Recce and transports need ECM upgrades. Just like the fighters and bombers.

10. Major, 3500 total flying hours, 101-200 combat flying hours:

   Question 48: Our preparation for combat is the best it can be. Desert Shield provided the opportunity to work directly with AWACS, as well as heavy-weight night refueling operations behind KC-10s. Combat will always be unpredictable, and preparing for it extremely difficult. However, simulators along with exercises

(Desert Shield) will keep us on the leading edge. It is paramount that we judge performance rather than potential.

C-130

Eleven C-130 pilots elected to include comment.

1. Major, 4300 total flying hours, less than 100 combat flying hours:

   Question 48: Another aspect to address is the participation of units/personnel in the humanitarian and Civil Military Operations that the U.S. has been increasingly involved in. Although not "combat," the small arms threat and ground threat exists in the environment crews are flying in, and in the airfield /dirt strip environment the support troops live in.

2. Captain, 1001-1500 total flying hours, less than 100 combat flying hours:

   Question 48: This survey should separate combat training to include Red Flag, from the real thing. We train a lot harder than we fight. Supporting Joint Endeavor and Southern Watch was much easier (less workload) than Red Flag or JRTC (a C-130 combat exercise). It was hard to generalize all combat environments to answer the questions, because each operation, or exercise is very unique to itself. Be careful of replacing bodies with technological advances. The C-130J is beginning to do this, and I am sure the workload for the pilots will increase. The navigator is integral to the success of the mission.

3. Major, 2501-3000 total flying hours, less than 100 combat flying hours:

   Question 48: I am just a C-130 pilot with limited time going into Bosnia. All of my crews' threat reactions were due to false alarms. I am sure the pucker factor, and alertness, would have gone up if a missile were to have gone whizzing by.

4. Captain, 1501-2000 total flying hours, less than 100 combat flying hours:

   Question 48: Technological updates to the older Hercules would be a huge help in advancing situational awareness and reducing workload. Many projects have been identified, but not funded. Fund them and the Hercules world will become much safer.

5. Major, 3850 total flying hours, less than 100 combat flying hours:

   Question 48: Daily battle plan issued to C-130s was very unwieldly. Not workable for emergency plans; too detailed without a good overall concept.

6. Major, 4500 total flying hours, less than 100 combat flying hours:

   Question 48: The C-130 Simulator Refresher Course at Little Rock AFB includes a scenario called the Mission Oriented Simulation Training (MOST). It is a simulated combat mission designed to assess Cockpit Resource Management (CRM) techniques and skills. It provides excellent training, and sounds very much like what you allude to in Questions 46, and 47.

7. Major, 3700 total flying hours, less than 100 combat flying hours:

   Question 48: Good, sound crew coordination and management can make or break the mission. Aircraft commanders must be familiar with the capabilities and limitations of his aircraft and crew. Knowing this can keep the options open in the changing combat environment. Time spent with a hard crew (the same crew members) increases this knowledge. I know that this is a broad statement, but it is a key to knowing how flexible you can be as situations change, and they will change in combat.

8. Captain, 2501-3000 total flying hours, 101-200 combat flying hours:

   Question 48: Reducing the number of crew members in the C-130 cockpit (even with technological advances) will at best cut the C-130 combat capability in half, and at worst, make it impossible or much too dangerous.

9. Captain, 2501-3000 total flying hours, less than 100 combat flying hours:

   Question 48: Although I volunteered to participate in an experimental study, it would not be a fair judgment of overall crew abilities. I am rather experienced. You would need to get young, "line" crews for reasonable results.

10. Captain, 2501-3000 total flying hours, less than 100 combat flying hours:

Question 46a: I do not want to any additional distractions in a combat flight environment.

11. Captain, 2501-3000 total flying hours, less than 100 combat flying hours:

Question 48: Our regulations are currently being updated and changed to Air Force Instructions (AFIs). Additionally, there have been so many changes to the operational guidance, crews cannot keep their publications updated

F-15

Twelve F-15 pilots included survey comments

1. Major, 2501-3000 total flying hours, 201-300 combat flying hours:

Question 48: I found that practicing tactics on training missions for seven years, allowed me to form habits which during the heat of battle caused me to react instinctively. (Habitual behavior) The bottom line is we need to practice. Flying and simulators; however, more in the aircraft.

2. Captain, 501-1000 total flying hours, less than combat flying hours:

Question 48: Twin engine, two seat fighters like the F-15E have a vast advantage in high threat missions. Tasks can be divided and full attention paid to a number of different tasks. Having the second engine to use as required immeasurably lowers the risk and stress level.

3. Major, 2501-3000 total flying hours, less than combat flying hours:

Question 46a: A combat sortie is inappropriate for testing. Where would the emphasis be—data collection or bombs on target? Would aircrews be required to perform nonstandard maneuvers, or fly in test modified aircraft? If the data collection was completely transparent, it might be acceptable.

4. Major, 2501-3000 total flying hours, 101-200 combat flying hours:

    Question 46a: The only true combat environment is a real one, and there have never been two that are same. Plus, I choose not to go to combat unless required, and do not plan to be part of an experiment during that time.

5. Major, 2501-3000 total flying hours, 101-200 combat flying hours:

    Question 48:Important elements missing from the combat workload items' listings are Communication Jamming or Degradation, Working as a Commander or Flight Lead in Large Composite Scenarios. Item 12, Adverse Weather: I interpreted to be the worst scenarios: target weather which drives me down into more lethal A3/MANPADs threat system(s); other weather issues include enroute and aerial refueling severe weather. Lastly, your survey did not mention the stress of operations in an NBC environment—even Saudi Arabia was a CW AOR!

6. Major, 2501-3000 total flying hours, 101-200 combat flying hours:

    Question 48: All the neat gee-whiz stuff in current fighters creates information overload, not less workload.

7. Major, 2001-2500 total flying hours, less than 100 combat flying hours:

    Question 48: Training is the key for workload management in combat. When I fly missions I have recently trained in, the workload is more manageable. Technology can help, and hurt your workload depending on the way it is applied. Technology without considering human factors in not good. Recent F-15 improvements which help eliminate workload include the MFD Situation Display and JTIDs. Although my unit did not have JTIDs, I have used it in the simulator. JTIDs is incredibly helpful and workload reducing for the air-to-air environment.

8. Major, 2001-2500 total flying hours, less than 100 combat flying hours:

    Question 48: Combat is too restrictive a term. I logged combat time during Operation Southern Watch. Much different environment than 0300 hours on 17 January 1991.

9. Major, 3400 total flying hours, 201-300 combat flying hours:

Question 48: Right now, the average fighter pilot's skills are less than when we fought the Desert Storm. Too many non-tactical TDYs like Southern Watch, Deny Flight, Roving Sands, etc. Last year, we could not go to Red / Green Flag, because of all the other bs...tasking. Skills after a FLAG exercise are always much higher. Doing more with less is taking its toll.

10. Major, 2501-3000 total flying hours, 301-400 combat flying hours:

Question 46a: No experiment is required. Come and talk to the crews. If you set up an experiment and not know what you are doing, the results will be too expensive and poorly aimed.

11. LTC, 2501-3000 total flying hours, less than 100 combat flying hours:

Question 48: Procedures have to be ingrained—second nature—during training sorties to prepare for combat. Pilots who attempt to learn their jet or do something off the shelf during a combat sortie tend not to get the desired results. Serious training is required.

12. Major, 2501-3000 total flying hours, less than 100 combat flying hours:

Question 48: You are wasting your time; however, in the above experiments, we practice harder scenarios than we actually see in combat. We have no way to simulate in peace, or the additional stress of knowing that death will be very real instead of an administrative kill--removal.

F-16

Eleven F-16 pilots wrote comments.

1. LTC, 2501-3000 total flying hours, 101-200 flying hours:

Question 48: The United States Air Force's technological advances, and tactical and operational improvements continue to provide quantum leaps in our ability project aerospace power.

2. LTC, 3100 total flying hours, 101-200 combat flying hours:

   Question 48:Training, lots of it, is the best way to help a pilot feel confident in his or her abilities, systems, and aircraft. Experience will better prepare someone to deal with the dynamics of the combat environment.

3. Captain, 1501-2000 total flying hours, less than 100 combat flying hours:

   Question 47a: Simulations, well, are just that, and I found it hard to believe that you could ever get over the fact you always at "1-G" flight.

   Question 48: We are hurting in the operations world just to get enough flights to stay current in all requirements, and do not get many opportunities to train in large force exercises, simulating combat. We deployed to Southwest Asia; flying there is so tame and over controlled. It detracts from our overall combat capability, therefore our stress level, if it actually happened.

4. Captain, 1001-1500 total flying hours, 101-200 combat flying hours:

   Question 48: There are a lot of "off-the-shelf" technologies that could reduce workload especially in combat environment. Onboard identification systems, moving maps, GPS, Datalink that are being delayed for political reasons. They could be the difference between surviving or perishing in a combat environment.

5. Major, 1501-2000 total flying hours, 101-200 combat flying hours:

   Question 48: First, your survey is too long which will affect the accuracy of your results—Human Reliability. Second, a horizontal situation display will reduce mental workload and free the resources to make tactical decisions. Also, we develop training scenarios that are tougher than many of the real world scenarios.

6. Major, 1501-2000 total flying hours, less than 100 combat flying hours:

   Question 46a: There should be no testing in combat.

Question 47a: No, I do not have time for one more TDY. I have already participated in a study that tries to increase the speed of a simulator (1.5 or 2X the normal speed) to help control things in air better.

7. Captain, 1501-2000 total flying hours, 301-400 combat flying hours:

   Question 48: "Real" combat versus contingency operations, that is Provide Comfort, is completely different as is a high air threat scenario, or a high-tech surface threat scenario in terms of workload and its effects on safety and mission accomplishment.

8. LTC, 3100 total flying hours, less than 100 combat flying hours:

   Question 48: The biggest concern I currently have about the Air Force preparing for combat is that we are training far less than the way we are expected to fight, due primarily to fiscal constraints, and the lack of spare parts. For monthly "bookkeeping" procedures, however, the reporting procedures have been changed to make it "appear" that the combat air forces are strong, when , in fact, they are not. I would not feel comfortable as a young pilot just starting out as opposed to being a seasoned pilot on the eve of my career, and able to retire in the near future. I strongly feel that these reasons are a major reason why pilot retention is becoming so severe.

9. Major, 2501-3000 total flying hours, 101-200 combat flying hours:

   Question 47a: A simulator is not the real thing as much as you try and make it so. My life and liberty are not on the line in the simulator.

10. Major, 1501-2000 total flying hours, less than 100 combat flying hours:

    Question 48: The restrictions that we operate under in peace time do not allow us to adequately prepare for combat. For example, we cannot go supersonic in the Military Operating Air Spaces (MOAS) we fly in. This means much of our air intercept training is unrealistic. Also, we are restricted from deploying chaff and flare in virtually every area we fly; this is also unrealistic, and hinders our training.

11. Captain, 501-1000 total flying hours, 101-200 combat flying hours:

Question 48: As the F-16C gains more and more combat missions—INT, DCA, FAC(A), SEAD, and CAS (I do not think that there are any other missions to give us.), pilots rely more on technology and aircraft ergonomics to make their jobs possible. Here is what we need:

1. NVGs
2. IFF interrogator
3. HSD

KC-135

Seven KC-135 crew members returned comments.

1. Captain, 2001-2500 total flying hours, less than 100 combat flying hours:

Question 48: We need RAW gear in the tanker aircraft.

2. Major, 2501-3000 total flying hours, less than 100 combat flying hours:

Question 48: For a KC-135, our job is pretty much the same in peace time and combat. The problems arise when it comes to threat detection. Currently, the KC-135 has no way of knowing of enemy aircraft location, or a missile launch. We depend heavily on AWACS for this type of information.

3. Major, 3200 total flying hours, 101-200 combat flying hours:

Question 46a: A combat environment is not the right place for experimental studies.

4. Captain, 1001-1500 total flying hours, less than 100 combat flying hours:

Question 48: KC-135 operations have moved away from "01"missions and possible environments, which is a good thing. Because, we have limited detect capability (if any), and no defense capability (chaff, flare, etc.)

5. Major, 3500 total flying hours, 201-300 combat flying hours:

   Question 48: This survey was directly aimed at fighter/bomber aircrews. Nothing wrong with this, but why survey tanker crew members. If the air force were serious about this for tankers, they would not be eliminating the navigator positions in the KC-135.

6. LTC, 3600 total flying hours, less than 100 combat flying hours:

   Question 48: The HQ staff at AMC and NAF staff are not willing to change the methods used in flight by the KC-135. Even the leadership addresses change, but the Air Force Instructions and Technical Orders do not address, or adapt to new ways of doing the job.

7. Captain, 1501-2000 total flying hours, 101-200 combat flying hours:

   Question 48: In the tanker world, we do the same peace-time missions as we would do in wartime missions, except for large formation refuelings—that is 4,5, or 6 ship formations. We did it everyday in the war, and in the aftermath of the war, but we stopped doing it years ago. So the skills and workload of pilots increase dramatically in very large formations.

Appendix C: SAS Computer Program

```
options linesize=80;
filename surveys 'surveyz.dat';
data temp;
infile surveys missover;
input @41 (Q1-Q48)(48*1.);
If Q8=0 then Q8=.;If Q8=1 then Q8=.;If Q5=. then Q5=0;
If (Q4=1 or Q4=4 or Q4=5) and Q3>2 and Q6>2 and Q5>0 then Q48=1;
If (Q4=2 or Q4=3 or Q4=6) and Q3>4 and Q6>3 and Q5>0 then Q48=1;
If Q48 ne 1 then Q48=0;
If Q9=6 then Q9=.;If Q10=6 then Q10=.;If Q11=6 then Q11=.;
If Q12=6 then Q12=.;If Q13=6 then Q13=.;If Q14=6 then Q14=.;
If Q15=6 then Q15=.;If Q16=6 then Q16=.;If Q17=6 then Q17=.;
If Q18=6 then Q18=.;If Q19=6 then Q19=.;If Q20=6 then Q20=.;
If Q21=6 then Q21=.;If Q22=6 then Q22=.;If Q23=6 then Q23=.;
If Q24=6 then Q24=.;If Q25=6 then Q25=.;If Q26=6 then Q26=.;
If Q27=6 then Q27=.;If Q28=6 then Q28=.;If Q29=6 then Q29=.;
If Q30=6 then Q30=.;If Q31=6 then Q31=.;If Q32=6 then Q32=.;
If Q33=6 then Q33=.;If Q34=6 then Q34=.;If Q35=6 then Q35=.;
If Q36=6 then Q36=.;If Q37=6 then Q37=.;
CWL=sum(Q10,Q11,Q12,Q14,Q15,Q16,Q17,Q18,Q19,Q20,Q21,Q22,Q23,
Q24,Q25,Q26,Q27,Q28,Q29,Q30,Q31,Q32,Q33,Q34,Q35,Q36,Q37);
Proc Format;
      Value Acft          1='A-10'
                          2='B-52'
                          3='C-130'
                          4='F-15'
                          5='F-16'
                          6='KC-135';
      Value Mission       1='Strategic Deterrence'
                          2='Conv. Hvy.Bmbg Ops'
                          3='Theater Airlift'
                          4='Tactical Airlift'
                          5='A/A Refling'
                          6='Air Superiority'
                          7='CAS'
                          8='Air Interdiction'
                          9='CAP'
                          0='Others';
      Value Exprnce       1='Experienced Pilot'
                          0='Inexperienced Pilot';
      Value TotFltHr      1='< 500 Hrs'
                          2='501-1,000 Hrs'
                          3='1,001-1,500 Hrs'
                          4='1,501-2,000 Hrs'
                          5='2,001-2,500 Hrs'
                          6='2,501-3,000 Hrs'
                          7='> 3,000 Hrs';
```

```
      Value ComFltHr      1='None'
                          2='< 100 Hrs'
                          3='101-200 Hrs'
                          4='201-300 Hrs'
                          5='301-400 Hrs'
                          6='400-500 Hrs'
                          7='> 500 Hrs';
      Value Rank          1='2nd Lt'
                          2='1st Lt'
                          3='Captain'
                          4='Major'
                          5='Lt Col'
                          6='Colonel';
      Value Gender        1='Female'
                          2='Male';
Proc Sort data=temp out=SortAC;
      Format Q4 Acft.;
      by Q4;
      run;
Proc Sort data=temp out=Missn;
      Format Q8 Mission.;
      by Q8;
      run;
Proc Sort data=temp out=exper;
      Format Q48 Exprnce.;
      by Q48;
      run;
Proc Print Data=SortAC;
      Format Q4 Acft.;
      Title 'Print-out of Entire Data with Aircraft Type';
      run;
Proc Freq Data=SortAC;
      Format Q1 Rank.;
      Format Q2 Gender.;
      Format Q3 TotFltHr.;
      Format Q6 ComFltHr.;
      Format Q8 Mission.;
      Format Q4 Acft.;
      Format Q48 Exprnce.;
      Title 'Frequency Print-out of Entire Data';
      run;
Proc Freq Data=SortAC;
      Format Q1 Rank.;
      Format Q2 Gender.;
      Format Q3 TotFltHr.;
      Format Q6 ComFltHr.;
      Format Q8 Mission.;
      Format Q4 Acft.;
      Format Q48 Exprnce.;
      Title 'Frequency Print-out by Aircraft Type';
      by Q4;
```

```
Proc Means Data=SortAC;
      Var  Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22
      Q23 Q24 Q25 Q26 Q27 Q28 Q29 Q30 Q31 Q32 Q33 Q34 Q35 Q36 Q37;
      Title 'Means of the Entire Critical Workload Factors';        run;
Proc Means Data=SortAC;
      Format Q4 Acft.;
      Var  Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22
      Q23 Q24 Q25 Q26 Q27 Q28 Q29 Q30 Q31 Q32 Q33 Q34 Q35 Q36 Q37;
      by Q4;
      Title 'Means of Critical Workload Factors Sorted by Aircraft
Type';
      run;
      Var  Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22
      Q23 Q24 Q25 Q26 Q27 Q28 Q29 Q30 Q31 Q32 Q33 Q34 Q35 Q36 Q37;
      by Q48;
      Title 'Means of the Entire Critical Workload Factors of all pilots
by Experience';
      run;
Proc Factor Data=SortAC simple nfact=2 reorder;
      Var  Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22 Q23
      Q24 Q25 Q26 Q27 Q28 Q29 Q30 Q31 Q32 Q33 Q34 Q35 Q36 Q37 Q38 Q39
      Q40 Q41 Q42 Q43 Q44 Q45 Q46 Q47;
      Title 'Factor Analysis of Combat Workload Factors';
      run;
Proc Corr Alpha Nocorr;
      Var Q10 Q11 Q12 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22 Q23
      Q24 Q25 Q26 Q27 Q28 Q29 Q30 Q31 Q32 Q33 Q34 Q35 Q36 Q37;
      Title 'Reliability Test of Combat Workload Factors';
      Run;
Proc Reg Data=temp;
      Model CWL=Q1 Q3 Q4 Q5 Q6 Q48 Q8/Selection=Stepwise AdjRsq;
      Title 'Stepwise Reg. of CWL --Entire Sample';
      Run;
Proc GLM Data=SortAC;
      Format Q4 Acft.;
      Class Q4;
      Model CWL=Q4 Q1 Q8 Q48 Q4*Q1 Q4*Q8 Q4*Q48 Q1*Q8 Q1*Q48 Q8*Q48;
      Means Q4/LSD BON SCHEFFE;
      Title 'Means Comparison of CWL by Aircraft Type';
      Run;
Proc Reg Data=SortAC;
      Model CWL=Q1 Q3 Q5 Q6 Q48 Q8/Selection=Stepwise AdjRsq;
      By Q4;
      Title 'Stepwise Reg. of CWL--By Aircraft Type';
      Run;
Proc Anova;
      Class Q4;
      Model CWL=Q4;
      Means Q4/LSD;
      Title 'Anova Procedure of Aircraft';
      run;
Proc Anova;
      Class Q6;
      Model CWL=Q6;
      Means Q6/LSD;
      Title 'Anova Procedure of Combat Flight Time';
      run;
```

```
Proc Anova;
      Class Q48;
      Model CWL=Q48;
      Means Q48/LSD;
      Title 'Anova Procedure of Experience';
      run;
Proc Anova;
      Class Q8;
      Model CWL=Q8;
      Means Q8/LSD;
      Title 'Anova Procedure of Mission Type';
      run;
END SAS;
```

Appendix D: Combat Workload Items' Ratings

Combat Workload Items by All Pilots:

Table D-1

Combat Workload Items Found to be Distractingly Important.

Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1. Threat Avoidance	2.2146	0.9358	1.0000	6.0000
2. In-flight Emergency	2.3059	0.9348	1.0000	6.0000

Table D-2

Combat Workload Items Found to be Moderately Important.

Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1. Fatigue	2.6303	1.1150	1.0000	6.0000
2. Crew Incapacitation	2.6303	1.9169	1.0000	6.0000
3. Adverse Weather	2.6575	1.0390	1.0000	6.0000
4. Aircraft Maneuvering (dogfight or avoiding threats)	2.7763	1.2922	1.0000	6.0000
5. In-flight, No-Notice Mission Changes	2.8493	0.9138	1.0000	6.0000
6. Equipment Degradation	2.9726	0.9857	1.0000	6.0000
7. Maintaining Situation Awareness	3.3288	1.1380	1.0000	6.0000
8. Threat Detection	3.3379	1.1982	1.0000	6.0000
9. Night Operations	3.3470	1.0310	1.0000	6.0000
10. Night Low Level Navigation	3.3562	1.6539	1.0000	6.0000
11. Terrain Avoidance/ Terrain Following	3.4658	1.3722	1.0000	6.0000

Table D-3

Combat Workload Items Found to be Somewhat Important.

Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1. Unfamiliar Terrain	3.6073	1.0968	1.0000	6.0000
2. Command and Control (such as copying & decoding EAMS)	3.6101	1.1558	1.0000	6.0000
3. Low Level Navigation	3.7397	1.2889	1.0000	6.0000
4. Managing Radio Communication	3.7580	0.9534	2.0000	6.0000
5. Formation Responsibilities	3.7854	0.9742	2.0000	6.0000
6. Target Acquisition	3.8174	1.3925	1.0000	6.0000
7. Visual Orientation	3.8940	1.1835	1.0000	6.0000
8. Responding Ground/ Air Radar Controller Instructions	4.0047	0.9262	1.0000	6.0000
9. Mission Planning	4.1046	1.1871	1.0000	6.0000
10. Management of TOT	4.1187	1.0021	1.0000	6.0000
11. Shifting Attention to Targets of Opportunity	4.1370	1.4032	1.0000	6.0000
12. Monitoring Flight Instruments	4.3014	0.8988	1.0000	6.0000
13. Crew Coordination	4.3699	1.3864	1.0000	6.0000
14. Type of Drop	4.5138	1.2152	2.0000	6.0000
15. Munitions Deployment	4.5160	1.2501	2.0000	6.0000
16. Refueling Operations	4.5982	0.9351	2.0000	6.0000

Combat Workload Items by Aircraft Type:

Table D-4

AO/A-10 Combat Workload Items Found to be Distractingly Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Threat Avoidance	1.9118	0.8658	1.0000	3.0000
2	In-flight Emergency	2.0588	0.6937	1.0000	4.0000
3	Adverse Weather	2.2941	0.9701	1.0000	5.0000
4	Aircraft Maneuvering	2.3529	1.1516	1.0000	5.0000
5	In-flight, No-Notice Mission Changes	2.5882	0.7434	1.0000	4.0000

Table D-5

AO/A-10 Combat Workload Items Found to be Moderately Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Night Operations	2.7941	0.8083	1.0000	4.0000
2	Night Low Level Navigation	2.7941	1.4518	1.0000	6.0000
3	Equipment Degradation	2.8235	0.9365	1.0000	5.0000
4	Fatigue	2.8235	1.1670	1.0000	5.0000
5	Target Acquisition	2.8529	0.8214	1.0000	4.0000
6	Threat Detection	2.9118	0.9001	1.0000	5.0000
7	Unfamiliar Terrain	3.0294	0.9996	1.0000	5.0000
8	Terrain Avoidance/ Terrain Following	3.1176	1.0945	1.0000	5.0000
9	Crew Incapacitation	3.1176	2.3583	1.0000	6.0000
10	Maintaining Situation Awareness	3.1765	1.1407	1.0000	5.0000
11	Low Level Navigation	3.3235	0.8428	1.0000	6.0000
12	Shifting Attention to Targets of Opportunity	3.4706	0.8956	1.0000	5.0000
13	Command and Control	3.5455	1.2271	1.0000	6.0000
14	Management of TOT	3.5882	0.8209	2.0000	5.0000

Table D-6

AO/A-10 Combat Workload Items Found to be Somewhat Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Managing Radio Communication	3.6471	0.8836	2.0000	5.0000
2	Responding to Ground/ Airborne Controller Instructions.	3.7576	0.9692	1.0000	5.0000
3	Munitions Deployment	3.7647	0.7808	2.0000	5.0000
4	Visual Orientation	3.8485	1.1214	1.0000	5.0000
5	Formation Responsibilities	3.9706	0.9370	2.0000	5.0000
6	Mission Planning	4.0000	1.2060	1.0000	6.0000
7	Type of Drop	4.0588	1.2778	2.0000	6.0000
8	Monitoring Flight Instruments	4.2941	0.9384	1.0000	5.0000
9	Refueling Operations	4.4412	0.7464	3.0000	5.0000

Table D-7

AO/A-10 Combat Workload Items Found to be A Little or Not Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Crew Coordination	4.9706	1.4031	1.0000	6.0000

Table D-8

B-52 Combat Workload Items Found to be Distractingly Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Crew Incapacitation	1.7692	1.0377	1.0000	5.0000
2	Threat Avoidance	1.8974	0.5523	1.0000	3.0000
3	Fatigue	2.0513	0.9162	1.0000	4.0000
4	Night Low Level Navigation	2.3077	1.0552	1.0000	6.0000
5	In-flight Emergency	2.4103	0.7152	1.0000	4.0000
6	Aircraft Maneuvering (Dogfight or avoiding the threats)	2.4103	1.0442	1.0000	6.0000

Table D-9

B-52 Combat Workload Items Found to be Moderately Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	In-flight, No-Notice Mission Changes	2.7179	0.6863	2.0000	4.0000
2	Adverse Weather	2.7179	1.1459	1.0000	5.0000
3	Terrain Avoidance/ Terrain Following	2.8205	1.0481	1.0000	6.0000
4	Night Operations	2.8462	1.0891	1.0000	6.0000
5	Equipment Degradation	2.8974	0.8206	1.0000	5.0000
6	Unfamiliar Terrain	3.0000	1.1239	1.0000	5.0000
7	Low Level Navigation	3.0513	0.8870	2.0000	6.0000
8	Maintaining Situation Awareness	3.0769	0.8701	1.0000	5.0000
9	Threat Detection	3.2051	0.8938	2.0000	5.0000
10	Crew Coordination	3.3333	1.0596	1.0000	5.0000
11	Target Acquisition	3.4615	0.9132	2.0000	5.0000
12	Managing Radio Communication	3.4615	0.9132	2.0000	5.0000
13	Command and Control	3.4615	1.0220	1.0000	5.0000
14	Formation Responsibilities	3.5128	0.7905	2.0000	5.0000

Table D-10

B-52 Combat Workload Items Found to be Somewhat Important.

	Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1	Responding to Ground/ Airborne Controller Instructions.	3.6410	1.0127	1.0000	5.0000
2	Management of TOT	3.6667	0.8057	2.0000	5.0000
3	Visual Orientation	3.6923	1.1955	1.0000	6.0000
4	Munitions Deployment	3.8205	0.9423	2.0000	5.0000
5	Type of Drop	4.0513	0.9986	2.0000	6.0000
6	Shifting Attention to Targets of Opportunity	4.0513	1.4318	1.0000	6.0000
7	Monitoring Flight Instruments	4.0769	0.8701	2.0000	5.0000
8	Refueling Operations	4.1282	1.0047	2.0000	6.0000
9	Mission Planning	4.3000	1.0670	2.0000	6.0000

Table D-11

C-130 Combat Workload Items Found to be Distractingly Important.

	Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1	Threat Avoidance	2.2500	0.8032	1.0000	4.0000
2	In-flight Emergency	2.5000	1.1359	1.0000	5.0000
3	Adverse Weather	2.5625	1.0453	1.0000	5.0000
4	Crew Incapacitation	2.5625	1.4797	1.0000	6.0000
5	Fatigue	2.5938	0.9456	1.0000	4.0000

Table D-12

C-130 Combat Workload Items Found to be Moderately Important.

Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1. Aircraft Maneuvering	2.6250	1.0080	1.0000	5.0000
2. In-flight, No-Notice Mission Changes	2.8437	1.1390	1.0000	5.0000
3. Command and Control	2.9063	0.9625	1.0000	4.0000
4. Terrain Avoidance/ Terrain Following	2.9375	1.0757	1.0000	6.0000
5. Maintaining Situation Awareness	2.9687	1.1496	1.0000	6.0000
6. Night Low Level Navigation	3.0937	1.1176	1.0000	6.0000
7. Managing Radio Communication	3.0938	0.7771	2.0000	4.0000
8. Threat Detection	3.1875	1.1760	1.0000	6.0000
9. Equipment Degradation	3.3125	1.0907	1.0000	5.0000
10. Low Level Navigation	3.3750	1.0395	1.0000	5.0000
11. Unfamiliar Terrain	3.3750	0.9419	1.0000	5.0000
12. Formation Responsibilities	3.4375	1.0140	2.0000	6.0000
13. Night Operations	3.4375	0.8007	2.0000	5.0000
14. Mission Planning	3.5000	1.2700	1.0000	6.0000
15. Crew Coordination	3.5625	1.1341	1.0000	5.0000

Table D-13

C-130 Combat Workload Items Found to be Somewhat Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Visual Orientation	3.6250	1.2889	1.0000	5.0000
2	Target Acquisition	3.6563	1.3586	1.0000	6.0000
3	Management of TOT	3.8125	0.9979	1.0000	5.0000
4	Responding to Ground/ Airborne Controller Instructions.	3.8667	0.9732	2.0000	5.0000
5	Monitoring Flight Instruments	4.0000	0.9837	2.0000	5.0000
6	Type of Drop	4.0625	1.0758	2.0000	6.0000

Table D-14

C-130 Combat Workload Items Found to be A Little or Not Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Shifting Attention to Targets of Opportunity	5.0000	1.6461	1.0000	6.0000

Table D-15

C-130 Combat Workload Items Found to be Not Applicable

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Munitions Deployment	5.6562	0.8654	2.0000	6.0000
2	Refueling Operations	5.7188	0.8126	3.0000	6.0000

Table D-16

F-15 Combat Workload Items Found to be Distractingly Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	In-flight Emergency	2.1613	1.0984	1.0000	6.0000
2	Crew Incapacitation	2.2258	1.9098	1.0000	6.0000
3	Threat Avoidance	2.2903	0.7829	1.0000	4.0000

Table D-17

F-15 Combat Workload Items Found to be Moderately Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1.	Aircraft Maneuvering	2.7419	1.3408	1.0000	6.0000
	(Dogfight or	2.7419	1.3408	1.0000	6.0000
	avoiding the threats)	2.7419	1.3408	1.0000	6.0000
2.	Fatigue	2.7742	1.2835	1.0000	5.0000
3.	Equipment Degradation	2.8387	1.0032	1.0000	5.0000
4.	Adverse Weather	2.8710	1.2843	1.0000	6.0000
5.	In-flight, No-Notice	2.8710	1.0876	1.0000	6.0000
	Mission Changes	2.8710	1.0876	1.0000	6.0000
6.	Terrain Avoidance/	3.3226	1.2217	1.0000	6.0000
	Terrain Following	3.3226	1.2217	1.0000	6.0000
7.	Shifting Attention to	3.3226	0.9447	2.0000	5.0000
	Targets of Opportunity	3.3226	0.9447	2.0000	5.0000
8.	Maintaining Situational	3.4516	0.9605	2.0000	5.0000
	Awareness	3.4516	0.9605	2.0000	5.0000
9.	Threat Detection	3.4839	0.8513	2.0000	5.0000

Table D-18

F-15 Combat Workload Items Found to be Somewhat Important.

	Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1	Target Acquisition	3.6452	1.1120	1.0000	6.0000
2	Night Operations	3.6774	0.9447	2.0000	6.0000
3	Low Level Navigation	3.7419	1.1823	2.0000	6.0000
4	Night Low Level Navigation	3.7419	1.4825	2.0000	6.0000
5	Command and Control (such as copying and decoding EAMS)	3.7419	1.2641	1.0000	6.0000
6	Unfamiliar Terrain	3.9355	0.9286	2.0000	6.0000
7	Munitions Deployment	4.0323	0.9826	2.0000	5.0000
8	Visual Orientation	4.0333	1.1885	1.0000	6.0000
9	Formation Responsibilities	4.1290	0.9217	3.0000	6.0000
10	Mission Planning	4.1613	1.1575	1.0000	6.0000
11	Managing Radio Communication	4.2581	0.7732	3.0000	6.0000
12	Management of TOT	4.2903	0.6925	3.0000	5.0000
13	Type of Drop	4.3333	1.2130	2.0000	6.0000
14	Responding to Ground/ Airborne Controller Instructions.	4.3871	0.8032	3.0000	6.0000
15	Monitoring Flight Instruments	4.4194	0.9228	2.0000	6.0000
16	Crew Coordination	4.4516	1.1207	1.0000	6.0000
17	Refueling Operations	4.5806	0.6720	3.0000	6.0000

Table D-19

F-16 Combat Workload Items Found to be Distractingly Important.

Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1 In-flight Emergency	2.2500	0.9675	1.0000	5.0000
2 Threat Avoidance	2.3636	1.2025	1.0000	6.0000

Table D-20

F-16 Combat Workload Items Found to be Moderately Important.

Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1. Adverse Weather	2.6364	0.8916	1.0000	4.0000
2. In-flight, No-Notice	2.8409	0.8877	1.0000	5.0000
Mission Changes	2.8409	0.8877	1.0000	5.0000
3. Fatigue	2.8864	1.1456	1.0000	6.0000
4. Aircraft Maneuvering	2.9091	1.1375	1.0000	6.0000
(Dogfight or	2.9091	1.1375	1.0000	6.0000
avoiding the threats)	2.9091	1.1375	1.0000	6.0000
5. Equipment Degradation	2.9773	0.9997	1.0000	5.0000
6. Night Operations	3.2727	1.0199	2.0000	6.0000
7. Threat Detection	3.3409	1.1195	1.0000	6.0000
8. Night Low Level	3.3636	1.5415	1.0000	6.0000
Navigation	3.3636	1.5415	1.0000	6.0000
9. Target Acquisition	3.4091	1.1875	2.0000	6.0000
10. Shifting Attention to	3.4773	0.9273	2.0000	5.0000
Targets of Opportunity	3.4773	0.9273	2.0000	5.0000
11. Maintaining Situation	3.5682	1.3364	1.0000	6.0000
Awareness	3.5682	1.3364	1.0000	6.0000
12. Crew Incapacitation	3.5909	2.2958	1.0000	6.0000

Table D-21

F-16 Combat Workload Items Found to be Somewhat Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Unfamiliar Terrain	3.8182	0.7857	2.0000	6.0000
2	Low Level Navigation	3.8182	0.9947	2.0000	6.0000
3	Terrain Avoidance/ Terrain Following	3.8182	1.2626	2.0000	6.0000
4	Visual Orientation	4.0455	1.2191	1.0000	6.0000
5	Munitions Deployment	4.0682	1.1081	2.0000	6.0000
6	Managing Radio Communication	4.2045	0.7947	2.0000	6.0000
7	Command and Control	4.2045	1.1729	2.0000	6.0000
8	Responding to Ground/ Airborne Controller Instructions.	4.2143	0.8421	2.0000	6.0000
9	Management of TOT	4.2500	0.8105	2.0000	6.0000
10	Mission Planning	4.2500	1.3316	1.0000	6.0000
11	Formation Responsibilities	4.2955	0.9296	2.0000	6.0000
12	Monitoring Flight Instruments	4.5227	0.8757	2.0000	6.0000
13	Type of Drop	4.5909	1.0414	2.0000	6.0000

Table D-22

F-16 Combat Workload Items Found to be A Little or Not Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Refueling Operations	4.6136	0.6893	3.0000	6.0000

Table D-23

F-16 Combat Workload Items Found to be Not Applicable

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Crew Coordination	5.7273	0.7270	3.0000	6.0000

Table D-24

KC-135 Combat Workload Items Found to be Distractingly Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Crew Incapacitation	2.3590	1.5129	1.0000	6.0000
2	In-flight Emergency	2.4359	0.9402	1.0000	5.0000
3	Threat Avoidance	2.5385	1.0475	1.0000	5.0000

Table D-25

KC-135 Combat Workload Items Found to be Moderately Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1.	Fatigue	2.6667	1.0596	1.0000	5.0000
2.	Adverse Weather	2.8462	0.8747	1.0000	5.0000
3.	Equipment Degradation	3.0000	1.0513	1.0000	6.0000
4.	In-flight, No-Notice	3.2051	0.8639	2.0000	5.0000
	Mission Changes	3.2051	0.8639	2.0000	5.0000
5.	Formation Responsibilities	3.3333	0.8686	2.0000	5.0000
6.	Aircraft Maneuvering	3.5128	1.6523	1.0000	6.0000
	(Dogfight or	3.5128	1.6523	1.0000	6.0000
	avoiding the threats)	3.5128	1.6523	1.0000	6.0000

Table D-26

KC-135 Combat Workload Items Found to be Somewhat Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Command and Control	3.6154	0.9351	2.0000	5.0000
2	Maintaining Situation Awareness	3.6410	1.1582	1.0000	6.0000
3	Managing Radio Communication	3.7949	1.0558	2.0000	5.0000
4	Refueling Operations	3.7949	1.0558	2.0000	5.0000
5	Threat Detection	3.8462	1.7702	1.0000	6.0000
6	Crew Coordination	3.9487	1.1227	1.0000	5.0000
7	Night Operations	4.0769	0.8701	2.0000	6.0000
8	Visual Orientation	4.0769	1.0854	1.0000	6.0000
9	Responding to Ground/ Airborne Controller Instructions.	4.1622	0.7643	3.0000	5.0000
10	Mission Planning	4.2821	0.9445	2.0000	6.0000
11	Unfamiliar Terrain	4.4103	1.0691	2.0000	6.0000
12	Monitoring Flight Instruments	4.4359	0.7538	2.0000	5.0000

Table D-27

KC-135 Combat Workload Items Found to be A Little or Not Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Terrain Avoidance/ Terrain Following	4.5641	1.6025	1.0000	6.0000
2	Night Low Level Navigation	4.7949	1.9219	1.0000	6.0000
3	Management of TOT	5.0000	1.1002	2.0000	6.0000
4	Low Level Navigation	5.0000	1.6222	1.0000	6.0000
5	Shifting Attention to Targets of Opportunity	5.4872	1.0729	2.0000	6.0000

Table D-28

KC-135 Combat Workload Items Found to be Not Applicable

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Target Acquisition	5.7436	0.7853	3.0000	6.0000
2	Type of Drop	5.7949	0.6561	3.0000	6.0000
3	Munitions Deployment	5.8205	0.7208	2.0000	6.0000

Combat Workload Items by Mission Type:

Table D-29

Conv. Hvy. Bomb. Missions' Combat Workload Items Found to be Distractingly Important.

Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1. Threat Avoidance	1.8611	0.5929	1.0000	3.0000
2 Crew Incapacitation	1.8611	1.2684	1.0000	6.0000
3 Fatigue	2.0556	0.9545	1.0000	4.0000
4 Night Low Level Navigation	2.2778	1.0853	1.0000	6.0000
5 In-flight Emergency	2.3611	0.6825	1.0000	4.0000
6 Aircraft Maneuvering (Dogfight or avoiding the threats)	2.4444	1.0541	1.0000	6.0000

Table D-30

Con. Hvy. Bomb. Missions' Combat Workload Items Found to be Moderately Important.

Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1. Adverse Weather	2.6667	1.2189	1.0000	5.0000
2. In-flight, No-Notice Mission Changes	2.6944	0.7099	2.0000	4.0000
3. Terrain Avoidance/ Terrain Following	2.8056	1.0907	1.0000	6.0000
4. Equipment Degradation	2.8611	0.8333	1.0000	5.0000
5. Night Operations	2.8611	1.1251	1.0000	6.0000
6. Low Level Navigation	2.9722	0.9098	2.0000	6.0000
7. Maintaining Situation Awareness	3.0000	0.8619	1.0000	5.0000
8. Unfamiliar Terrain	3.0278	1.0552	1.0000	5.0000
9. Threat Detection	3.2222	0.9292	2.0000	5.0000
10. Crew Coordination	3.3056	1.0907	1.0000	5.0000
11. Target Acquisition	3.3889	0.9644	2.0000	5.0000
12. Command and Control	3.3889	1.0764	1.0000	5.0000
13. Managing Radio Communication	3.4167	0.9063	2.0000	5.0000
14. Formation Responsibilities	3.4722	0.8102	2.0000	5.0000
15. Responding to Ground/ Airborne Controller Instructions.	3.5833	1.0247	1.0000	5.0000

Table D-31

Con. Hvy. Bomb. Missions' Combat Workload Items Found to be Somewhat Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1.	Management of TOT	3.6111	0.8028	2.0000	5.0000
2	Visual Orientation	3.6389	1.2225	1.0000	6.0000
3	Munitions Deployment	3.8333	0.9710	2.0000	5.0000
4	Type of Drop	3.9167	0.9673	2.0000	6.0000
5	Shifting Attention to Targets of Opportunity	3.9167	1.4417	1.0000	6.0000
6	Monitoring Flight Instruments	4.0278	0.9098	2.0000	5.0000
7	Refueling Operations	4.1667	0.9710	2.0000	6.0000
8	Mission Planning	4.2432	1.0905	2.0000	6.0000

Table D-32

Theater Airlift Missions' Combat Workload Items Found to be Distractingly Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1.	Threat Avoidance	2.0000	0.5774	1.0000	3.0000
2	In-flight Emergency	2.2308	1.0919	1.0000	5.0000
3	Crew Incapacitation	2.3077	1.2506	1.0000	5.0000
4	Adverse Weather	2.3846	0.7679	1.0000	4.0000

Table D-33

Theater Airlift Missions' Combat Workload Items Found to be Moderately Important.

	Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1.	Fatigue	2.6154	0.9608	1.0000	4.0000
2.	Aircraft Maneuvering	2.6923	0.9473	1.0000	4.0000
3.	In-flight, No-Notice Mission Changes	2.6923	1.0316	1.0000	5.0000
4.	Command and Control	2.8462	0.8987	2.0000	4.0000
5.	Managing Radio Communication	3.0000	0.7071	2.0000	4.0000
6.	Maintaining Situation Awareness	3.0000	0.8165	1.0000	4.0000
7.	Equipment Degradation	3.0769	1.0377	1.0000	4.0000
8.	Night Low Level Navigation	3.0769	1.1152	2.0000	6.0000
9.	Threat Detection	3.1538	0.8006	2.0000	4.0000
10.	Terrain Avoidance/ Terrain Following	3.1538	1.0682	2.0000	6.0000
11.	Low Level Navigation	3.2308	0.8321	2.0000	5.0000
12.	Unfamiliar Terrain	3.4615	0.6602	2.0000	4.0000
13.	Formation Responsibilities	3.5385	0.9674	2.0000	6.0000
14.	Visual Orientation	3.5385	1.3301	1.0000	5.0000

Table D-34

Theater Airlift Missions' Combat Workload Items Found to be Somewhat Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Night Operations	3.6154	0.7679	3.0000	5.0000
2	Crew Coordination	3.6154	0.9608	2.0000	5.0000
3	Target Acquisition	3.6154	1.2609	2.0000	6.0000
4	Mission Planning	3.6923	1.3775	2.0000	6.0000
5	Management of TOT	3.7692	0.5991	3.0000	5.0000
6	Monitoring Flight Instruments	3.9231	0.8623	3.0000	5.0000
7	Responding to Ground/ Airborne Controller Instructions.	4.0000	0.7746	3.0000	5.0000
8	Type of Drop	4.2308	0.9268	3.0000	6.0000

Table D-35

Theater Airlift Missions' Combat Workload Items Found to be A Little or Not Important

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Shifting Attention to Targets of Opportunity	5.0000	1.6330	2.0000	6.0000

Table D-36

Theater Airlift Missions' Combat Workload Items Found to be Not Applicable

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Munitions Deployment	5.6923	0.6304	4.0000	6.0000
2	Refueling Operations	5.6923	0.8549	3.0000	6.0000

Table D-37

Tactical Airlift Missions' Combat Workload Items Found to be Distractingly Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Threat Avoidance	2.2778	0.8264	1.0000	3.0000
2	Fatigue	2.4444	0.9218	1.0000	4.0000
3	In-flight Emergency	2.5556	1.1991	1.0000	5.0000

Table D-38

Tactical Airlift Missions' Combat Workload Items Found to be Moderately Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1.	Adverse Weather	2.6667	1.1376	1.0000	5.0000
2.	Aircraft Maneuvering	2.6667	1.1376	1.0000	5.0000
3.	Crew Incapacitation	2.6667	1.7150	1.0000	6.0000
4.	Terrain Avoidance/ Terrain Following	2.7778	1.1144	1.0000	4.0000
5.	Maintaining Situation Awareness	2.7778	1.2154	1.0000	6.0000
6.	Command and Control	2.8333	1.0432	1.0000	4.0000
7.	Night Low Level Navigation	3.0000	1.0847	1.0000	5.0000
8.	In-flight, No-Notice Mission Changes	3.0000	1.2367	1.0000	5.0000
9.	Threat Detection	3.0556	1.2590	1.0000	6.0000
10.	Managing Radio Communication	3.1111	0.8324	2.0000	4.0000
11.	Mission Planning	3.2222	1.1660	1.0000	5.0000
12.	Night Operations	3.2778	0.7519	2.0000	4.0000
13.	Unfamiliar Terrain	3.3333	1.1376	1.0000	5.0000
14.	Equipment Degradation	3.3889	1.0922	1.0000	5.0000
15.	Low Level Navigation	3.3889	1.1448	1.0000	5.0000
16.	Formation Responsibilities	3.4444	1.0416	2.0000	5.0000
17.	Crew Coordination	3.4444	1.2472	1.0000	5.0000
18.	Visual Orientation	3.5556	1.2935	1.0000	5.0000

Table D-39

Tactical Airlift Missions' Combat Workload Items Found to be Somewhat Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Target Acquisition	3.7222	1.4473	1.0000	6.0000
2	Responding to Ground/ Airborne Controller Instructions.	3.7778	1.0603	2.0000	5.0000
3	Management of TOT	3.8889	1.2314	1.0000	5.0000
4	Type of Drop	3.9444	1.2113	2.0000	6.0000
5	Monitoring Flight Instruments	4.0000	1.0847	2.0000	5.0000

Table D-40

Tactical Airlift Missions' Combat Workload Items Found to be A Little or Not Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Shifting Attention to Targets of Opportunity	4.9444	1.7311	1.0000	6.0000

Table D-41

Tactical Airlift Missions' Combat Workload Items Found to be Not Applicable.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Munitions Deployment	5.6111	1.0369	2.0000	6.0000
2	Refueling Operations	5.8889	0.4714	4.0000	6.0000

Table D-42

A/A Refueling Missions' Combat Workload Items Found to be Distractingly Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Crew Incapacitation	2.4324	1.5191	1.0000	6.0000
2	In-flight Emergency	2.4865	0.9316	1.0000	5.0000
3	Threat Avoidance	2.5676	1.0682	1.0000	5.0000

Table D-43

A/A Refueling Missions' Combat Workload Items Found to be Moderately Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1.	Fatigue	2.6757	1.0815	1.0000	5.0000
2.	Adverse Weather	2.8649	0.8870	1.0000	5.0000
3.	Equipment Degradation	3.0000	1.0801	1.0000	6.0000
4.	In-flight, No-Notice Mission Changes	3.2432	0.8630	2.0000	5.0000
5.	Formation Responsibilities	3.3514	0.8569	2.0000	5.0000
6.	Aircraft Maneuvering (Dogfight or avoiding the threats)	3.5405	1.6765	1.0000	6.0000

Table D-44

A/A Refueling Missions' Combat Workload Items Found to be Somewhat Important.

	Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1	Maintaining Situation Awareness	3.6216	1.1868	1.0000	6.0000
2	Command and Control	3.6757	0.9145	2.0000	5.0000
3	Managing Radio Communication	3.8378	1.0675	2.0000	5.0000
4	Threat Detection	3.8378	1.7562	1.0000	6.0000
5	Crew Coordination	3.9459	1.1291	1.0000	5.0000
6	Night Operations	4.0811	0.8938	2.0000	6.0000
7	Visual Orientation	4.1351	1.0843	1.0000	6.0000
8	Responding to Ground/ Airborne Controller Instructions.	4.1714	0.7854	3.0000	5.0000
9	Refueling Operations	4.2973	0.8119	3.0000	5.0000
10	Mission Planning	4.3514	0.9194	2.0000	6.0000
11	Unfamiliar Terrain	4.4054	1.0919	2.0000	6.0000
12	Monitoring Flight Instruments	4.4595	0.7672	2.0000	5.0000

Table D-45

A/A Refueling Missions' Combat Workload Items Found to be A Little or Not Important.

	Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1	Terrain Avoidance/ Terrain Following	4.6486	1.5849	1.0000	6.0000
2	Night Low Level Navigation	4.8108	1.9413	1.0000	6.0000
3	Management of TOT	5.0000	1.1055	2.0000	6.0000
4	Low Level Navigation	5.0270	1.6242	1.0000	6.0000
5	Shifting Attention to Targets of Opportunity	5.4595	1.0953	2.0000	6.0000

Table D-46

A/A Refueling Missions' Combat Workload Items Found to be Not Applicable.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Target Acquisition	5.8108	0.6599	3.0000	6.0000
2	Type of Drop	5.8108	0.6599	3.0000	6.0000
3	Munitions Deployment	5.8108	0.7393	2.0000	6.0000

Table D-47

Air Superiority Missions' Combat Workload Items Found to be Distractingly Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Fatigue	2.0000	1.0690	1.0000	4.0000
2	Threat Avoidance	2.2500	0.7071	1.0000	3.0000
3	In-flight Emergency	2.3750	1.1877	1.0000	5.0000
4	Adverse Weather	2.5000	1.3093	1.0000	4.0000

Table D-48

Air Superiority Missions' Combat Workload Items Found to be Moderately Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1.	Terrain Avoidance/ Terrain Following	2.7500	1.2817	1.0000	5.0000
2.	Crew Incapacitation	2.7500	2.4349	1.0000	6.0000
3.	Night Operations	3.0000	0.7559	2.0000	4.0000
4.	In-flight, No-Notice Mission Changes	3.1250	0.9910	2.0000	5.0000
5.	Aircraft Maneuvering (Dogfight or avoiding the threats)	3.1250	1.2464	2.0000	5.0000
6.	Threat Detection	3.3750	1.0607	2.0000	5.0000
7.	Low Level Navigation	3.5000	1.3093	2.0000	6.0000

Table D-49

Air Superiority Missions' Combat Workload Items Found to be Somewhat Important.

	Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1	Equipment Degradation	3.6250	0.7440	3.0000	5.0000
2	Shifting Attention to Targets of Opportunity	3.7500	0.8864	3.0000	5.0000
3	Maintaining Situation Awareness	3.8750	0.9910	3.0000	5.0000
4	Command and Control (such as copying and decoding EAMS)	3.8750	1.3562	2.0000	6.0000
5	Unfamiliar Terrain	4.0000	1.0690	2.0000	5.0000
6	Managing Radio Communication	4.1250	0.6409	3.0000	5.0000
7	Munitions Deployment	4.2500	0.8864	3.0000	5.0000
8	Formation Responsibilities	4.2500	1.0351	3.0000	5.0000
9	Mission Planning	4.2500	1.0351	3.0000	5.0000
10	Target Acquisition	4.2500	1.0351	3.0000	6.0000
	Monitoring Flight Instruments	4.3750	1.0607	2.0000	5.0000
11	Night Low Level Navigation	4.5000	1.8516	2.0000	6.0000
12	Visual Orientation	4.5714	0.7868	3.0000	5.0000

Table D-50

Air Interdiction Missions' Combat Workload Items Found to be A Little or No Important.

Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
Management of TOT	4.7500	0.4629	4.0000	5.0000
Responding to Ground/ Airborne Controller Instructions.	4.7500	0.4629	4.0000	5.0000
Refueling Operations	4.8750	0.3536	4.0000	5.0000
Type of Drop	5.5714	0.7868	4.0000	6.0000

Table D-51

Air Interdiction Missions' Combat Workload Items Found to be Not Applicable.

Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1 Crew Coordination	5.6250	0.7440	4.0000	6.0000

Table D-52

CAS Missions' Combat Workload Items Found to be Distractingly Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Threat Avoidance	1.8462	0.8339	1.0000	3.0000
2	In-flight Emergency	2.1154	0.7114	1.0000	4.0000
3	Adverse Weather	2.3462	1.0561	1.0000	5.0000
4	Aircraft Maneuvering (Dogfight or avoiding the threats)	2.3846	1.0612	1.0000	4.0000
5	In-flight, No-Notice Mission Changes	2.5385	0.8115	1.0000	4.0000

Table D-53

CAS Missions' Combat Workload Items Found to be Moderately Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1.	Fatigue	2.8077	1.0961	1.0000	5.0000
2.	Night Low Level Navigation	2.8077	1.4702	1.0000	6.0000
3.	Night Operations	2.8462	0.7317	2.0000	4.0000
4.	Equipment Degradation	2.8462	1.0077	1.0000	5.0000
5.	Threat Detection	2.9231	1.0168	1.0000	6.0000
6.	Target Acquisition	2.9615	0.8709	2.0000	5.0000
7.	Terrain Avoidance/ Terrain Following	3.0385	1.1129	1.0000	5.0000
8.	Crew Incapacitation	3.0385	2.2712	1.0000	6.0000
9.	Unfamiliar Terrain	3.0769	0.9348	1.0000	5.0000
10.	Maintaining Situation Awareness	3.1923	1.2967	1.0000	6.0000
11.	Low Level Navigation	3.3462	0.8918	1.0000	6.0000
12.	Shifting Attention to Targets of Opportunity	3.4615	0.8593	1.0000	5.0000
13.	Management of TOT	3.5000	0.8124	2.0000	5.0000

Table D-54

CAS Missions' Combat Workload Items Found to be Somewhat Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Command and Control (such as copying and decoding EAMS)	3.6000	1.2583	1.0000	6.0000
2	Munitions Deployment	3.7692	0.9081	2.0000	6.0000
3	Managing Radio Communication	3.7692	0.9923	2.0000	5.0000
4	Responding to Ground/ Airborne Controller Instructions.	3.8000	0.9574	1.0000	5.0000
5	Visual Orientation	3.8800	1.2356	1.0000	6.0000
6	Formation Responsibilities	3.9615	0.9992	2.0000	5.0000
7	Mission Planning	4.0000	1.1662	1.0000	6.0000
8	Type of Drop	4.1923	1.2967	2.0000	6.0000
9	Monitoring Flight Instruments	4.4231	0.8566	3.0000	6.0000
10	Refueling Operations	4.5385	0.6469	3.0000	5.0000

Table D-55

CAS Missions' Combat Workload Items Found to be A Little or No Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Crew Coordination	5.1154	1.3950	1.0000	6.0000

Table D-56

Air Interdiction Missions' Combat Workload Items Found to be Distractingly Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	In-flight Emergency	2.2593	1.0494	1.0000	6.0000
2	Threat Avoidance	2.4259	1.0569	1.0000	6.0000

Table D-57

Air Interdiction Missions' Combat Workload Items Found to be Moderately Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1.	Aircraft Maneuvering (Dogfight or avoiding the threats)	2.7407	1.3202	1.0000	6.0000
2.	Adverse Weather	2.8148	1.0108	1.0000	6.0000
3.	Equipment Degradation	2.8519	0.9398	1.0000	5.0000
4.	In-flight, No-Notice Mission Changes	2.9259	0.9286	1.0000	6.0000
5.	Crew Incapacitation	2.9444	2.1841	1.0000	6.0000
6.	Fatigue	2.9815	1.2052	1.0000	6.0000
7.	Night Low Level Navigation	3.3333	1.2439	2.0000	6.0000
8.	Target Acquisition	3.3519	1.1186	1.0000	6.0000
9.	Shifting Attention to Targets of Opportunity	3.4259	0.9235	2.0000	5.0000
10.	Threat Detection	3.4259	0.9437	2.0000	6.0000
11.	Maintaining Situation Awareness	3.5370	1.1770	1.0000	6.0000
12.	Night Operations	3.5556	1.0031	2.0000	6.0000

Table D-58

Air Interdiction Missions' Combat Workload Items Found to be Somewhat Important.

	Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1	Terrain Avoidance/ Terrain Following	3.6296	1.0692	2.0000	6.0000
2	Unfamiliar Terrain	3.7778	0.9842	1.0000	6.0000
3	Low Level Navigation	3.7963	0.9393	2.0000	6.0000
4	Munitions Deployment	4.0000	1.0279	2.0000	6.0000
5	Command and Control (such as copying and decoding EAMS)	4.0000	1.2439	1.0000	6.0000
6	Visual Orientation	4.0556	1.1396	1.0000	6.0000
7	Managing Radio Communication	4.1667	0.7709	3.0000	6.0000
8	Management of TOT	4.1852	0.7542	2.0000	6.0000
9	Responding to Ground/ Airborne Controller Instructions.	4.1923	0.8641	2.0000	6.0000
10	Formation Responsibilities	4.2222	0.8831	2.0000	6.0000
11	Mission Planning	4.2407	1.3022	1.0000	6.0000
12	Type of Drop	4.2963	1.0751	2.0000	6.0000
13	Monitoring Flight Instruments	4.4630	0.8625	2.0000	6.0000
14	Refueling Operations	4.5741	0.7423	3.0000	6.0000

Table D-59

Air Interdiction Missions' Combat Workload Items Found to be A Little or Not Important.

	Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1	Crew Coordination	4.8333	1.1935	1.0000	6.0000

Table D-60

CAP Missions' Combat Workload Items Found to be Distractingly Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	In-flight Emergency	2.0000	0.9428	1.0000	4.0000
2	Threat Avoidance	2.3000	1.0593	1.0000	4.0000

Table D-61

CAP Missions' Combat Workload Items Found to be Moderately Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1.	In-flight, No-Notice Mission Changes	2.7000	0.6749	2.0000	4.0000
2.	Adverse Weather	2.8000	1.0328	2.0000	5.0000
3.	Equipment Degradation	2.8000	1.3166	1.0000	5.0000
4.	Fatigue	3.0000	1.3333	1.0000	5.0000
5.	Threat Detection	3.2000	1.2293	1.0000	5.0000
6.	Aircraft Maneuvering (Dogfight or avoiding the threats)	3.2000	1.2293	1.0000	5.0000
7.	Shifting Attention to Targets of Opportunity	3.3000	0.6749	2.0000	4.0000
8.	Crew Incapacitation	3.4000	2.5473	1.0000	6.0000
9.	Unfamiliar Terrain	3.5000	0.8498	2.0000	5.0000

Table D-62

CAP Missions' Combat Workload Items Found to be Somewhat Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Command and Control (such as copying and decoding EAMS)	3.6000	1.0750	2.0000	6.0000
2	Night Operations	3.6000	1.0750	2.0000	6.0000
3	Visual Orientation	3.6000	1.1738	1.0000	5.0000
4	Maintaining Situation Awareness	3.7000	0.9487	2.0000	5.0000
5	Target Acquisition	3.7000	1.1595	2.0000	5.0000
6	Night Low Level Navigation	3.8000	1.8738	1.0000	6.0000
7	Low Level Navigation	4.1000	1.2867	2.0000	6.0000
8	Mission Planning	4.3000	0.8233	3.0000	5.0000
9	Managing Radio Communication	4.3000	0.9487	2.0000	5.0000
10	Refueling Operations	4.3000	0.9487	2.0000	5.0000
11	Munitions Deployment	4.3000	1.1595	2.0000	6.0000
12	Type of Drop	4.3000	1.2517	2.0000	6.0000
13	Formation Responsibilities	4.4000	0.8433	3.0000	5.0000
14	Responding to Ground/ Airborne Controller Instructions.	4.5000	0.7071	4.0000	6.0000
15	Terrain Avoidance/	4.5000	1.3540	2.0000	6.0000
	Terrain Following	4.5000	1.3540	2.0000	6.0000

Table D-63

CAP Missions' Combat Workload Items Found to be A Little or Not Important.

Combat Workload Item		Mean	Std. Dev.	Minimum	Maximum
1	Management of TOT	4.6000	0.6992	3.0000	5.0000
2	Monitoring Flight Instruments	4.7000	0.4830	4.0000	5.0000

Table D-64

CAP Missions' Combat Workload Items Found to be Not Applicable

Combat Workload Item	Mean	Std. Dev.	Minimum	Maximum
1 Crew Coordination	5.7000	0.4830	5.0000	6.0000

Miscellaneous Data:

Table D-65a

Initial Factor Method: Principal Components

Item #	Combat Workload Items	Factor Pattern	
		Factor 1	Factor 2
Q16	Night Low Level Navigation	0.77231	0.3244
Q15	Low Level Navigation	0.74182	0.15369
Q29	Crew Coordination	0.73364	0.08411
Q25	In-flight Emergency	0.67657	-0.30689
Q33	Night Operations	0.66906	0.36405
Q34	Unfamiliar Terrain	0.66027	0.20675
Q10	Terrain Avoidance/Terrain Following	0.65754	0.19341
Q18	Formation Responsibilities	0.65611	0.12035
Q37	Responding to Ground/Airborne	0.59703	0.01568
	Controller Instructions.	0.59703	0.01568
Q20	In-flight, No-Notice Mission Changes	0.59356	-0.32371
Q19	Management of TOT	0.59326	-0.03848
Q30	Aircraft Maneuvering	0.57372	-0.04129
Q26	Visual Orientation	0.56825	-0.04454
Q14	Equipment Degradation	0.55536	-0.18587
Q31	Target Acquisition	0.55124	0.03632
Q17	Threat Avoidance	0.53988	0.13651
Q32	Type of Drop	0.53782	-0.19364
Q22	Munitions Deployment	0.53643	-0.27001

Table D-65b

Initial Factor Method: Principal Components

Item #	Combat Workload Items	Factor Pattern	
		Factor 1	Factor 2
Q11	Maintaining Situation Awareness	0.5331	-0.1363
Q24	Crew Incapacitation	0.5056	-0.2816
Q36	Refueling Operations	0.5049	-0.0790
Q28	Fatigue	0.4894	-0.0199
Q23	Threat Detection	0.4523	-0.0227
Q27	Command and Control	0.4142	-0.3795
Q35	Managing Radio Communication	0.4008	0.0404
Q21	Shifting Attention to Targets of Opportunity	0.3845	-0.6094
Q12	Adverse Weather	0.3635	0.0828
Q9	Mission Planning	0.2832	-0.0513
Q13	Monitoring Flight Instruments	0.2831	0.0552
Q42	Combat versus Peace time	0.2590	0.0544
Q41	Updating the Regulations	0.2299	0.5101
Q43	Simulator Effectiveness	0.1679	0.3826
Q47	Volunteering Sim Exp.s	0.1447	0.3603
Q39	Modifying the Cockpit	0.0838	0.3985
Q46	Volunteering Combat Exp.s	0.0346	0.4744
Q44	US and Allies' Air Power	0.0340	0.5416
Q40	Technological Innovations	0.0255	0.5674
Q45	Combat Realities	-0.0121	0.2766
Q38	Additional Crew Member	-0.0206	-0.0097
		Factor 1	Factor 2
	Variance Explained by Each Factor	9.273758	2.982069

Table D-66

Reliability Test of CWL

Correlation Analysis --Cronbach Coefficient Alpha
for RAW variables : 0.920502
for STANDARDIZED variables: 0.922903

		Raw Variables		Std. Variables	
Item #	Deleted Variables Combat Workload Factors	Correlation with Total	Alpha	Correlation with Total	Alpha
Q15	Low Level Navigation	0.6263	0.9163	0.6300	0.9186
Q29	Crew Coordination	0.6188	0.9161	0.6173	0.9188
Q19	Management of TOT	0.6186	0.9165	0.6196	0.9188
Q33	Night Operations	0.6108	0.9164	0.6165	0.9189
Q32	Type of Drop	0.6065	0.9165	0.6160	0.9189
Q16	Night Low Level Navigation	0.5972	0.9165	0.6025	0.9191
Q31	Target Acquisition	0.5859	0.9167	0.5973	0.9192
Q37	Responding to Ground/ Airborne Controller Instructions	0.5775	0.9170	0.5757	0.9195
Q18	Formation Responsibilities	0.5749	0.9169	0.5788	0.9194
Q20	In-flight, No-Notice Mission Changes	0.5681	0.9171	0.5711	0.9196
Q17	Threat Avoidance	0.5678	0.9171	0.5764	0.9195
Q30	Aircraft Maneuvering	0.5638	0.9171	0.5696	0.9196
Q26	Visual Orientation	0.5596	0.9172	0.5558	0.9198
Q34	Unfamiliar Terrain	0.5547	0.9172	0.5576	0.9198
Q10	Terrain Avoidance/ Following	0.5418	0.9174	0.5442	0.9200
Q28	Fatigue	0.5279	0.9177	0.5265	0.9203
Q25	In-flight Emergency	0.5205	0.9178	0.5164	0.9204
Q14	Equipment Degradation	0.4943	0.9182	0.4912	0.9208
Q11	Maintaining Situation Awareness	0.4791	0.9185	0.4852	0.9209
Q21	Shifting Attention to Targets of Opportunity	0.4659	0.9186	0.4749	0.9210
Q27	Command and Control	0.4614	0.9187	0.4586	0.9213
Q23	Threat Detection	0.4607	0.9187	0.4687	0.9211
Q35	Managing Radio Communication	0.4588	0.9187	0.4640	0.9212
Q22	Munitions Deployment	0.4547	0.9188	0.4664	0.9212
Q12	Adverse Weather	0.4030	0.9197	0.3996	0.9222
Q36	Refueling Operations	0.4001	0.9194	0.4049	0.9221
Q24	Crew Incapacitation	0.3767	0.9209	0.3790	0.9225

Table D-67

Result of Bonferroni Procedure--Comparison of Aircraft's Mean CWL Scores

Aircraft Comparison		Lower Confidence Limit	Difference Between Means	Upper Confidence Limit	Significance
F-15	- F-16	-8.846	1.985	12.816	
F-15	- B-52	-4.945	5.675	16.294	
F-15	- A-10	-4.080	6.911	17.902	
F-15	- C-130	1.058	12.228	23.398	***
F-15	- KC-135	6.922	17.477	28.033	***
F-16	- F-15	-12.816	-1.985	8.846	
F-16	- B-52	-6.671	3.690	14.051	
F-16	- A-10	-5.816	4.926	15.668	
F-16	- C-130	-0.682	10.243	21.168	
F-16	- KC-135	5.196	15.492	25.788	***
B-52	- F-15	-16.294	-5.675	4.945	
B-52	- F-16	-14.051	-3.690	6.671	
B-52	- A-10	-9.292	1.236	11.765	
B-52	- C-130	-4.162	6.553	17.268	
B-52	- KC-135	1.729	11.802	21.875	***
A-10	- F-15	-17.902	-6.911	4.080	
A-10	- F-16	-15.668	-4.926	5.816	
A-10	- B-52	-11.765	-1.236	9.292	
A-10	- C-130	-5.767	5.317	16.400	
A-10	- KC-135	0.102	10.566	21.030	***
C-130	- F-15	-23.398	-12.228	-1.058	***
C-130	- F-16	-21.168	-10.243	0.682	
C-130	- B-52	-17.268	-6.553	4.162	
C-130	- A-10	-16.400	-5.317	5.767	
C-130	- KC-135	-5.403	5.249	15.901	
KC-135	- F-15	-28.033	-17.477	-6.922	***
KC-135	- F-16	-25.788	-15.492	-5.196	***
KC-135	- B-52	-21.875	-11.802	-1.729	***
KC-135	- A-10	-21.030	-10.566	-0.102	***
KC-135	- C-130	-15.901	-5.249	5.403	

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Vita

1st Lieutenant Kadircan Kottas was born in Tarsus, Turkey on April 8, 1969. He graduated from Maltepe Military High School in Izmir, in 1987, and entered the Turkish Air Force Academy in November of the same year. On August 30, 1991, he graduated from the Air Force Academy in Istanbul, where he received a Bachelor of Science degree in Aeronautical Engineering. Upon his graduation, he was commissioned as a 2nd Lieutenant, and he attended the Undergraduate Pilot Training (UPT) at Cigli AFB, Izmir. After completing the Basic Flight Training Phase, he was selected to continue UPT in the United States. Lieutenant Kottas earned his wings upon completing the Intermediate and Advanced Flight Training at Laughlin AFB, Texas on March 19, 1993. Following Fighter Lead Training at Konya AFB, Turkey, he was assigned to Akinci AFB, Ankara, where he received F-16 Orientation Training. After completing this training, he was assigned to the 191st Tactical Squadron at Balikesir AFB, Turkey. Lieutenant Kottas participated in Operations Provide Comfort and Decisive Endeavor over Northern Iraq and Bosnia, respectively. Later, he was selected to study for a graduate degree at the United States Air Force Institute of Technology, specializing in Logistics Management. Lieutenant Kottas has accumulated over 450 hours of flying time. Upon graduation, he will continue flying as a fighter pilot at Balikesir AFB.

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13. ABSTRACT (*Maximum 200 Words*)

This study analyzed the self-reported survey responses of 219 Air Force Pilots concerning their perceptions of workload assessment in a combat or a high-threat environment. The first objective of this study was to determine and compare the combat workload factors of varying importance in combat workload assessment by aircraft and mission type flown. The second objective was to examine the pilots' perception of combat mission in-flight workload. A stepwise regression model to predict the pilots' perceptions of in-flight workload using pilots' characteristics data was explored. Research conclusion varied among aircraft types. Combat workload items indicated as "distractingly" important were similar for all aircraft types, while items in lower level of importance were impacted by aircraft type. Mean Combat Workload (CWL) scores of pilots from each aircraft type were not significantly different. Overall, it was concluded that surveying pilots who had flown in combat or high-threat environments provided useful responses to assess pilot workload; however, findings based on subjective assessments, provide tentative grounds for further research.

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